STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
A. M. SHELTON, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

BULLETIN NO. 54

OIL AND GAS DEVELOPMENT AND POSSIBILITIES IN EAST-CENTRAL ILLINOIS

(Clark, Coles, Douglas, Edgar, and parts of adjoining counties)

BY

L. A. MYLIUS

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1927

STATE OF ILLINOIS

DEPARTMENT OF REGISTRATION AND EDUCATION

A. M. SHELTON, *Director*

DIVISION OF THE

STATE GEOLOGICAL SURVEY

M. M. LEIGHTON, *Chief*

BULLETIN NO. 54

S IN

ERRATA

TEXT

Page	Line	
7	9 and 25	"Pennsylvanian", not "Pennsylvania"
11	19	"Recommendations", not "Recomendations"
13	1	"available for examination," instead of "given in Chapter VII"
13	12	Title of Pl. XXIII, "contoured", not "contained"
13	37	Title of figure 2, insert ";" after "coralliferous".
31	6	Change "from and to" to "to and from"
56	36	In analysis of shale, "dioxide", not "lioxide"
161	Next to last	"green", not "red"
162	Line 2, 2nd paragraph	"red", not "green"
162	Line 1, last paragraph	Omit "in red on"
163	Line 1, 1st paragraph	"red", not "green"

PLATE

XXII-C	legend for green contour: "in the Bellair pool", not "of the Bellair pool"
XXIII	Horizon G., legend: omit "in red on" Horizon J., legend: "red", not "green"
XXIV	legend: transpose "Approximate edge of Older Pennsylvanian" and "Approximate edge of Chester". In other words, the long dashes represent the edge of the "Older Pennsylvanian", the short dashes the edge of the Chester.
XXVI	title: last line, "see Plate XXII-A", not "see Plate XXII-B". Add note at end: "(A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.)"
XXIX	title: "Structure contour map of the Martinsville pool"
XXXI	title: change "red" to "green", and "green" to "red" legend: transpose legends for red and green contours. In other words, the green contours represent Horizon G, the 500-foot sand, and the red contours represent Horizon J, the 800-foot sand.

1927

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
A. M. SHELTON, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

BULLETIN NO. 54

OIL AND GAS DEVELOPMENT AND POSSIBILITIES IN EAST-CENTRAL ILLINOIS

(CLARK, COLES, DOUGLAS, EDGAR AND PARTS OF ADJOINING COUNTIES)

BY

L. A. MYLIUS

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1927

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
A. M. SHELTON, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

JEFFERSONS PRINTING & STATIONERY CO.
SPRINGFIELD, ILLINOIS
1927

PREFACE

The data for this bulletin were gathered and compiled by Mr. L. A. Mylius during his employment by the Survey, covering a period of several years. Before leaving the Survey in 1923 to enter the commercial field, Mr. Mylius completed the manuscript, and an abstract entitled "Oil and Gas Development and Possibilities in Parts of Eastern Illinois" was immediately printed. This abstract contained the author's recommendations for further prospecting in a large area in and near the main eastern oil fields, but the reasons for many of his conclusions could not be set forth in the smaller volume, and much detailed data were necessarily left for the larger report.

Because of lack of printing funds, the Survey was obliged to hold the manuscript of the complete volume for some time. As soon as funds became available, the manuscript was edited, and it is now issued without the author's review or reading of its contents with the exception of some specific portions dealing with purely scientific matters, which the Survey officially referred to him. The report does not include data or interpretation of data later than the early part of 1923. Consequently in applying this report it is important to consider all phases as of that date.

Editorial preparation of the author's manuscript for the press, necessitating a technical understanding of the author's data and ideas, has been made by Nellie Barrett Rich, who was in touch with the work during her former connection with the Survey.

The detailed logs mentioned in the report are available either upon personal application or upon written request to the Chief of the Survey. The Survey wishes to emphasize this service in order that those who wish to do so may examine the basis for some of the conclusions drawn in the report.

M. M. Leighton, *Chief,*
State Geological Survey Division.

CONTENTS

ILLUSTRATIONS

(PLATES IN BULLETIN)

(PLATES IN CASE)

(FIGURES)

TABLES

OIL AND GAS DEVELOPMENT AND POSSIBILITIES IN EAST-CENTRAL ILLINOIS—CLARK, COLES, DOUGLAS, EDGAR, AND PARTS OF ADJOINING COUNTIES

By L. A. Mylius

CHAPTER I—INTRODUCTION

PURPOSE OF REPORT

It is the primary purpose of this report to assist operators in prospecting for and production of petroleum within the area outlined in figure 1, which comprises principally Douglas, Edgar, Clark and Coles counties, with parts of adjoining counties.

Within the area are included the oldest of the important oil pools of Illinois. Parts of many of them were developed so long ago that well data are difficult to obtain. It has been considered important, therefore, to compile and preserve herein all the well data obtainable for the field. In addition the report comprises studies of the geology and structure of the area, and of operating methods and problems, as well as suggestions and recommendations for improvement of recovery and discovery of new production.

PLAN OF REPORT

Chapter II is intended either as a summarized survey of the entire field, complete in itself, or as an introduction to the more detailed chapters that follow, depending on the interest and purpose of individual readers.

Chapter III is devoted to the stratigraphic, structural, and historical geology of the area as a whole, and Chapter IV to notes on the use of logs, cuttings, and cores.

Chapter V considers miscellaneous problems of operation and production, having special bearing on increased economy and efficiency and possible improvement in methods of recovery.

Chapter VI comprises detailed descriptions of the individual pools.

Chapter VII makes recommendations for future prospecting in the area.

The map case included as part of this bulletin contains the many maps, cross-sections, and diagrams that were too large to be bound with the book conveniently, and in addition it contains the large Tables of Well Data which give the more important log and drilling data for more than 5,000 wells and dry holes in the Clark County field.

In order to avoid repetition, many of the subjects considered from one angle in one chapter have had to be considered from other angles in other chapters.

For this reason and for the reason that in many instances data presented in widely separated parts of the book are very closely interrelated, the reader is especially urged to make full use of the Index, in order that he may be certain not to overlook any material bearing on his particular problem or interest.

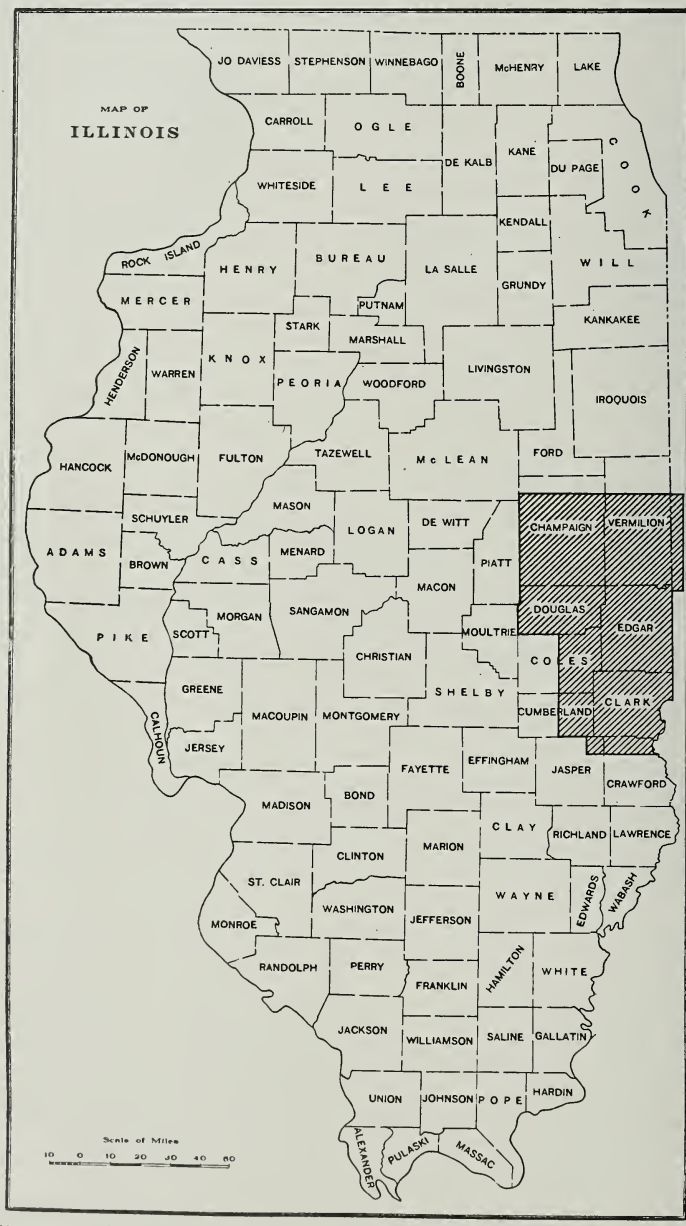


Fig. 1. Index map of Illinois showing by shading the area covered by this report.

METHODS OF STUDY

In the Field

As many wells and dry holes as possible have been located, and their curb elevations and locations obtained by a plane-table survey which followed the establishment of level traverse bench marks. An endeavor has been made to acquire complete details of the rock section in each locality by procuring as many logs as possible. Samples of drill cuttings have been obtained from the holes drilled during the progress of the investigation and some samples from earlier drilling have been available. Well behavior and operating conditions and methods have been observed and noted wherever possible.

In the Office

All the available logs have been studied thoroughly to establish a geological basis for contouring and interpreting the behavior of the various "sands," and for correlating the geologic formations and systems.

Contour maps and other types of maps, geological sections, and illustrations have been prepared, and the sand, shot, and production records and other practical details regarding the wells and dry holes of each pool have been tabulated and all logs carefully correlated. Careful studies have been made of (1) the nature and variations of structure, (2) the rock section, and (3) the geological history, particularly as to their bearing on commercial oil production, and their application to future oil prospecting, development, and improved operating methods.

ACKNOWLEDGMENTS

It is not possible to list the names of the oil men who contributed data for the preparation of this report. A cordial spirit of cooperation has been outstanding and without the help given by companies and their officials, individual operators, drillers, helpers, leasemen, and others associated with the oil industry in the area, this report would have been impossible.

The leveling of wells, started by Mr. J. Marvin Weller and continued by Mr. D. J. Fisher, has been completed by Mr. D. M. Collingwood to whom the greater share of that work is to be credited. Mr. Collingwood has also ably assisted in obtaining field information, and spent a very considerable time on the contouring of sands and in the construction of the Tables of Well Data. This assistance has been invaluable.

Messrs. J. E. Lamar and A. W. Thurston have studied most of the well samples, and Mr. Thurston and Mr. L. Fortier have examined most of the cores.

The writer wishes also to acknowledge the assistance of other members of the Survey staff, more especially Dr. T. E. Savage, who has been consulted frequently regarding stratigraphic problems and Dr. H. E. Culver who has given assistance in problems relating to the Pennsylvanian correlations.

The writer is indebted to former Chief F. W. DeWolf who has directed the investigation and has given critical suggestions on all phases of the report.

CHAPTER II—SUMMARY

INTRODUCTION

Chapter II is intended to serve either as a summarized survey of the Clark County field and its vicinity, complete in itself, or as an introduction to the more detailed chapters that follow, depending on the interests and purpose of the reader. Its aim is to give the reader a general idea of the importance of the field, of its broader geologic features, of its characteristic operating methods and problems, and of the nature of its future possibilities.

LOCATION, EXTENT, AND SUBDIVISIONS OF THE AREA

The area considered in this report is outlined in figure 1. It includes those parts of Champaign and Vermilion counties south of T. 21 N.; most of Douglas, Edgar, and Clark counties; the eastern half of Coles County; the eastern part of Cumberland County; the northwestern part of Crawford County, specifically, T. 8 N., Rs. 13 and 14 W.; and the northeastern corner of Jasper County.

Within this area, which comprises more than 3,000 square miles, the producing pools are restricted to ten townships in Coles, Cumberland, Clark, and Crawford counties, namely: Westfield (T. 12 N., R. 14 W.); Hutton and Parker (T. 11 N., Rs. 10 and 11 E. and 14 W.); Union, Casey, and Martinsville (T. 10 N., Rs. 10 and 11 E. and 13 and 14 W.); Crooked Creek, Johnson, and Orange (T. 9 N., Rs. 10 and 11 E. and 13 and 14 W.); and Licking[1] (T. 8 N., R. 14 W.). These townships have a total area of about 400 square miles, of which 38 square miles, or 24,300 acres, are productive of oil and gas.

Practically all the important pools lie either in or very close to Clark County, and consequently the name *Clark County field* is used in this report in referring to the pools collectively. The individual pools are known as Westfield or Parker, Siggins, York, main and north Casey, Martinsville, Johnson, and Bellair pools, all of which are outlined on Plates I and XXI. Plate XXII, in three parts, is a large-scale map of the Clark County field which shows the locations of all the known oil and gas wells and dry holes in the various pools.

Most of the gas produced in the Clark County field was closely associated with the oil, and much more gas was produced with the oil than from gas wells. The localities where gas was encountered in more important amounts than oil were in Westfield Township (T. 12 N., R. 14 W.) northeast of the oil production; in north-central Casey Township (T. 10 N., R. 14 W.) close to and associated with the oil production in that pool; in southwestern Martinsville, eastern Johnson and northwestern Orange townships in a zone east of and approximately paralleling the main zone of oil production; in the Siggins pool, secs. 24, 25, and 30; and also in the Bellair pool, from the 800-foot sand.

In addition to outlining the producing pools, Plate XXI outlines also the geologic sub-areas into which the area has been divided. The subdivision seemed advisable because of the marked irregularity and variation of the rock section from place to place. Within each sub-area (A, B, C, etc.), a characteristic set of geologic conditions seems to prevail, differentiating it from the other sub-

[1]Only that part of Licking Township in and near the Bellair pool is considered in this report

areas. It must not be overlooked, however, that the division has been based on incomplete data and that the exact boundaries of the sub-areas are therefore purely arbitrary. Table 4, page 32, summarizes the geologic conditions for each sub-area.

HISTORY OF THE CLARK COUNTY FIELD

A history of the discovery and development of petroleum in the Clark County field will be found in earlier bulletins[2] but will be repeated here for convenience and brought up to date.

In 1866 a company called the Clark County Petroleum and Mining Company was organized with its office at Marshall, Illinois. The indications of petroleum responsible for the formation of this company consisted of natural gas escapages at several places in Parker Township (T. 11 N., R. 14 W.), Clark County. The failure of the company to produce oil commercially was no doubt due in part to inability at that time to case off water. The K. and E. Young farm, sec. 17, Parker Township, was the center of these early attempts to produce oil.

In 1904 Colonel L. D. Carter of Oakland, Illinois, leased a large block of acreage in the same vicinity, and interested Mr. James Hoblitzel of Pittsburgh, Pennsylvania, in prospecting the block with the drill. The first test, drilled in the southwest corner of the Young farm, sec. 17, Parker Township, resulted in a gas well. The first oil production was obtained from a well on the Spellbring farm, in August, 1905, and the same year other wells were completed on the J. S. Phillips and Mary Lee farms. By 1907, the Parker Township pool as it is today was practically outlined.

The discovery of other pools soon followed. The Siggins pool in Union Township, Cumberland County, was discovered in 1906, and its limits defined by about 1907. The Casey Township production was outlined by drilling from 1906 to 1908, and the Johnson Township production from 1907 to 1908. The Bellair pool in Licking Township, Crawford County, was drilled up from 1908 to 1910. Deeper pays were found in the Westfield lime in the Parker Township pool about 1908 from which time the general deepening over the whole field probably dates. By 1909, at least 75 per cent of the present wells had been drilled, and at that time the extreme depth of any of the pay horizons was about 900 feet.

In 1910 the Ohio Oil Company drilled the K. and E. Young well No. 79 in sec. 17, Parker Township, to the "Trenton," obtaining a small well in that horizon from 2,300 to 2,400 feet. In 1912 the same company drilled another "Trenton" well, the Young No. 84, in the same section. The third well to be drilled to this horizon was located on the O. N. Smith farm, in sec. 5, Parker Township and its completion in September, 1919, marked the beginning of a moderate drilling campaign to the "Trenton."

---

[2]Blatchley, W. S., The petroleum industry of southeastern Illinois: Illinois State Geol. Survey Bull. 2, 1906.

Blatchley, R. S., The oil fields of Crawford and Lawrence counties: Illinois State Geol. Survey Bull. 22, 1913.

STATISTICS OF PRODUCTION

Oil

Table 1 gives the annual production of petroleum in barrels for Clark, Coles, and Cumberland counties for the years 1905 to 1920, inclusive, based on production statistics compiled by the United States Geological Survey. The production of the Bellair pool is not included for the reason that that pool lies partly in Clark and partly in Crawford County, and all of its production happens to have been arbitrarily included in the Crawford County totals.

Table 2 summarizes the economic data for the individual pools and for the field as a whole. It is based partly on production statistics and partly on detailed maps of the pools, in conjunction with logs and other detailed data for

Table 1.—*Annual production of petroleum in barrels, 1905-1920 Clark, Coles, and Cumberland counties*

Year	Clark *a*	Coles	Cumberland
1905	181,084	......	....
1906	4,397,050	......	....
1907	1,651,917	14,000	500,937
1908	1,286,794	10,300	363,323
1909	4,091,483	32,861	1,468,721
1910	4,309,525	45,928	1,456,159
1911	4,432,799	54,625	1,415,397
1912	4,991,278	32,132	1,102,128
1913	2,893,881	36,679	1,102,331
1914	2,764,674	39,263	934,010
1915	2,176,300	36,441	789,702
1916	2,011,271	11,224	673,367
1917	1,810,266	4,409	515,936
1918	1,786,785	12,932	560,854
1919	1,717,690	25,678	527,560
1920	1,352,903	10,507	450,325

*a*Not including production of Bellair pool.

approximately 6,000 wells and dry holes. All the available detailed economic data for individual wells are included in the Tables of Well Data which will be found in the map case.

... which can be tabulated is

3Annually a large amount of gas is used for drilling, power, etc., which is not reported.

STATISTICS OF PRODUCTION

*a*Not including production of Bellair pool.

approximately 6,000 wells and dry holes. All the available detailed economic data for individual wells are included in the Tables of Well Data which will be found in the map case.

Practically all the available economic material which can be tabulated is incorporated in Table 2 and the Tables of Well Data, with the result that careful study of their many details will give a better idea of the past and present condition of the field as a whole, and a better basis for comparison of the pools than would pages of description.

Gas

The statistics of gas production for the Clark County field are so far from complete that they could not be tabulated to advantage.

Gas was produced both from gas wells and along with the oil. Indeed, the oil wells so far outnumbered the gas wells, that although each oil well contributed but a small amount of gas, the total quantity of gas thus produced was far greater than the total quantity from gas wells.

The following paragraphs give an approximate idea of the total amount of gas produced as well as the production of individual wells.

FIELD TOTALS

In 1906 and 1907—years during which most of the gas produced in Illinois must have come from Clark and Cumberland counties because active development in Crawford and Lawrence counties had not yet begun—approximately 700 million and 1,150 million cubic feet respectively were reported[3] for the State. During 1908 and 1909 Crawford and Lawrence counties were being "drilled up" and must have contributed a very considerable portion of the State production. What fraction of the 1909 State total of approximately 8,472 million cubic feet should be attributed to the Clark County field cannot be estimated even roughly; but surely the fraction was small. The available 1914 statistics indicate a recorded production of less than one-fourth million cubic feet for the field, and those for the following year, 1915, still less. After the installation of vacuum, which began to be common about 1915, the amount of gas increased somewhat.

PRODUCTION FROM INDIVIDUAL WELLS

The meager data available indicate that but few wells in the Clark County field produced in excess of 2 or 3 million cubic feet of gas per day initially, and most of them considerably less.

In the early days of the field, in 1905 and 1906, the maximum initial rock pressure per square inch was about 200 pounds, but by 1909 it was generally less than 100 pounds and by 1913 less than 30 pounds.

All the gas wells have been abandoned for many years, but much gas is still produced from oil wells. The present daily gas production per well is estimated to vary from 500 to 4,000 cubic feet per day, the smaller productions from the smaller oil wells, the larger from the larger oil wells. The average is between 1,000 and 1,500 cubic feet.

---

[3]Annually a large amount of gas is used for drilling, power, etc., which is not reported.

The general installation of vacuum has tended to increase the production of gas per well, because a lessening of the pressure induces the release of gases held under very slight pressure in the oil and also causes the vaporization of some of the hydrocarbons normally liquid.

CHARACTER OF THE OIL

The analyses of 21 samples of oil taken in various localities and at various sand horizons in the Clark County field are given in Table 3. Samples No. 1 to No. 19 inclusive were all analyzed prior to the recommendations of the Bureau of Mines.[4] Their analyses are therefore not in as convenient form as are the analyses for samples No. 20 and No. 21, which conform to the Bureau's recommendations.

An interesting expression of the marked difference between the "Trenton" and Lower Mississippian lime oils is that the "Trenton" oils tend to "wax up" the sucker rods, but the wax may be eliminated very simply by running the Lower Mississippian oil into the "Trenton" wells when the trouble appears. The "Trenton" oil has a notably high gasoline and kerosene content.

As a result of the general installation of vacuum, the Baumé gravity of the crude oil produced in the field has decreased slightly. The lowering of the pressure by the gas pump causes the release of gas that is normally held, and also the vaporization of hydrocarbons that are liquid under higher pressures.

METHODS AND PROBLEMS OF OPERATION AND PRODUCTION

Leases

The greater part of the Clark County field was leased under the one-eighth royalty for oil and $100.00 per gas well agreement. But considerable acreage carries one-sixth royalty, and on leases whose production is well below the average of the field this difference in royalty has already been felt. In rare instances acreage was leased on a minimum rental rate per acre per year.

Drilling

Drilling of wells in the Clark County field presents no outstanding difficulties and the usual methods are employed. Only those features relating particularly to the area will be considered.

WATER FOR DRILLING

Water for drilling is obtained either from a shallow well penetrating a water-bearing sand or gravel bed above bed rock; or by laying a 2-inch pipe line to the nearest drainage ditch or stream—commonly a short distance except in midsummer. Potable and boiler waters are rarely found below the top of the bed rock.

[4] Rittman, W. F., and Dean, E. W., The analytical distillation of petroleum: U. S. Bur. of Mines Bull. 125, 1916.

SHUT-OFFS

One or more salt water sands occur generally above the oil-producing sand. (See Chapter V.) With the exception of Licking and parts of Johnson Town... and in the case of "Trenton" wells (see Table 16), only one string of cas-

b
Sample number
Laboratory number
Baume gravity at 15° C.
Specific gravity at 15° C.
Fractional distillation
Percentage distilled at 150° C.
Percentage distilled from 150°
Percentage distilled from 225° t
Percentage distilled over 300° C
Percentage of coke residue
Percentage of loss on distillatio
Nature of the base *f*
Color of distillate *g*
0° to 150° C.
150° to 225° C.
225° to 300° C.
Over 300° C.
Water *h*

a Chemist... Moose, Univer...

b Samples... tions of the U... to the public... the samples t... right of that

for example, at a time when three ... maximum depth was only 900 feet and the average depth probably less than 400 feet. Since then, most of the wells have been deepened to lower pays, bringing the averages up to the figures given in Table 2.

SPACING OF WELLS

Table 2 gives the average spacing of wells in the various pools and the field as a whole. Rarely were wells spaced closer than 4.4 acres per well or 9 wells for 40 acres. An exception is the drilling of 70 wells on 120 acres

The general installation of vacuum has tended to increase the production of gas per well, because a lessening of the pressure induces the release of gases held under very slight pressure in the oil and also causes the vaporization of some of the hydrocarbons normally liquid.

WATER FOR DRILLING

Water for drilling is obtained either from a shallow well penetrating a water-bearing sand or gravel bed above bed rock; or by laying a 2-inch pipe line to the nearest drainage ditch or stream—commonly a short distance except in midsummer. Potable and boiler waters are rarely found below the top of the bed rock.

[4]Rittman, W. F., and Dean, E. W., The analytical distillation of petroleum: U. S. Bur. of Mines Bull. 125, 1916.

SHUT-OFFS

One or more salt water sands occur generally above the oil-producing sand. (See Chapter V.) With the exception of Licking and parts of Johnson Town ship and in the case of "Trenton" wells (see Table 16), only one string of casing, generally landed on the top of the sand, is needed in addition to the drive pipe. In places, liners are used where several pay streaks without intervening salt water necessitate some amount of open hole. The Tables of Well Data give casing records.

CASING SEATS

In general little difficulty is experienced in seating the casing so as completely to shut off water from above, as the recurring thin shells, or the limestones, as well as the thick shales, overlying the pay sands, make ideal casing seats. The comparatively few exceptions will be discussed in Chapter V.

SHOT

Table 2 includes shot data for the individual pools and for the field as a whole. The Tables of Well Data give the shot records for many individual wells.

Most of the wells were shot when drilled and practically all the few natural wells were shot later. For the field as a whole the statement is true that "the shot made the well." The sands that showed practically no free oil seemed to benefit most by the shooting, and for most wells the benefit was to a greater or lesser degree permanent. Certainly many wells could never have produced commercial amounts of oil without a shot. The inadequate data at hand seem to indicate that as a rule a benefit of at least 3:1 was obtained by shooting.

"Double shooting" of wells when they are first drilled has rarely been tried. If the total amount of nitroglycerine used is no greater, double shooting of tight sands that need to be fractured as much as possible is of no greater benefit than single shooting. But for porous sand, two or more small shots will produce a larger hole and should therefore give greater improvement than a single shot using the same amount of nitroglycerine.

In most parts of the field, the pipe was pulled before shooting and little difficulty was experienced in reseating the casing. But some of the Chester sands seemed to be permanently hurt by even temporary exposure to salt water and the practice has arisen of shooting these sands without removing the casing.

DEPTH OF WELLS

The maximum, minimum, and average present depths of the wells in the Clark County field as a whole and in the various pools are given in Table 2. In the early days of the field, the wells were in general shallower. In 1909, for example, at a time when three-fourths of the wells had been drilled, the maximum depth was only 900 feet and the average depth probably less than 400 feet. Since then, most of the wells have been deepened to lower pays, bringing the averages up to the figures given in Table 2.

SPACING OF WELLS

Table 2 gives the average spacing of wells in the various pools and the field as a whole. Rarely were wells spaced closer than 4.4 acres per well or 9 wells for 40 acres. An exception is the drilling of 70 wells on 120 acres

locally in the Siggins pool. The "Trenton" wells, 12 in number to date, are spaced about like the gas wells, four or five to 40 acres.

COSTS

Drilling costs for the shallow wells in the early days of the field were 90 cents to $1.00 per foot, for drilling only. In recent years the price has been somewhat higher. For the 1,400-foot wells of the Martinsville pool, developed in 1922, the costs were $2.00 to $2.50 per foot for 1922 to 1923 respectively. The still deeper "Trenton" wells, all drilled since 1920, cost from $2.50 to $3.00 per foot.

Operation

The routine methods of operation will be ignored in this report, and only certain of the unusual aspects and difficulties will be considered.

FLOATING SAND

Floating sand caused considerable trouble in many parts of the Clark County field, rapidly cutting off the cups in the working barrel. The trouble occurred most commonly where the sands are very thick (30 to 75 feet). Probably such thicknesses comprise considerable quantities of very fine sandstone interbedded with the more porous and more prolific coarser sand, and the shooting of thick sands must have loosened large quantities of fine sand. "Over shooting" of some sands may also have brought about the trouble by breaking the larger sand grains into small angular fragments.

WATER LIFTING

Much water must be lifted in producing the oil from some horizons in some parts of the field. Most of such water is either "bottom-water" or water even more intimately associated with the oil.

"Bottom-water" of the type successfully cemented off in Lawrence and Crawford counties[5] occurs in the Bellair and Johnson Township pools. In parts of the area such water has already been cemented off, but in other parts many wells stand in need of attention.

The water found in most intimate association with the pay in all probability has its source in comparatively thin water sands interbedded with pay streaks. Obviously, to shut off such water is not practicable and large quantities of water must be handled with the oil. It has been noted, however, that in the Parker Township pool, the many years of pumping have greatly reduced the amount of water and lowered the general water horizon, thereby permitting deepening of the wells through lower pay streaks and recovery of oil that in earlier years could not be reached because of the prohibitive quantities of water encountered at those depths at that time.

CORROSION

The corrosion of casing, lead lines, and tubing is a trouble common to many parts of the Clark County field, but is felt most acutely in parts of the Parker Township pool. An extreme example of pipe corrosion is illustrated in figure 8.

[5]Tough, F. B., Williston, S. H., and Savage, T. E., Experiments in water control in the Flat Rock pool, Crawford County: Illinois State Geol. Survey Bull. 40, pp. 97-140, 1919.

In general the bottom joints of the casing corrode most rapidly. The pipe is corroded both outside and inside, but the outside corrosion presents the more serious problem.

Tubing corrosion is on the whole a lesser difficulty, but lead line corrosion is very troublesome locally. In extreme instances, new lead lines on some leases in the Parker Township pool have lasted but three months.

Continued efforts are being made to combat corrosion, for the replacement of casing, tubing and lead lines involves large expenditures and in many instances leads to the abandonment of leases long before their oil yields would become too low to justify further pumping.

Analyses of waters from the various geological horizons in the Clark County field are given in Table 14, Chapter V.

CUT OIL

On the whole, cut oil was not a serious trouble in the Clark County field. In small isolated localities, oil from certain sands had a tendency to cut, but at the present time cutting is a negligible difficulty. However, with the coming adoption of compressed gas, which may increase the cutting tendency, it may become advantageous to study the association of oil cutting with the different mineral concentrations of salt water.

USE OF GAS

When the field was first drilled, Casey, Martinsville, Marshall, local smaller towns, and towns in Crawford County used the gas. Now the gas lines have been taken up and the gas not used to operate the leases is burned in flares. The total amount wasted in flare burning is considerable, but probably would not justify the cost of installation and maintenance of gathering lines.

"WAXING UP" OF "TRENTON" RODS

The tendency of "Trenton" rods to "wax up" every few weeks promised to be troublesome until it was found that pouring Mississippian oil into the "Trenton" wells occasionally removed the accumulated wax and eliminated the necessity of pulling tubing.

VACUUM (GAS PUMP)

Except for the North Casey and Martinsville pools, practically the whole Clark County field is now on the gas pump and has been so since 1918. At the time vacuum was installed, the wells averaged 10 to 10½ years old.

Table 15, comprising data for typical leases, gives an idea of the benefit derived from the use of the gas pump over the field as a whole.

COMPRESSED AIR OR GAS

The use of compressed air or gas is still in the experimental stage in the Clark County field. It is clear that lease productions can be increased by this process, but whether or not profitably at present has not yet been definitely demonstrated.

The use of compressed air alone or even a mixture of air and gas is looked upon with some disfavor because the supply of gas for fuel is already so low that

its deterioration or further decrease, which would follow as a result of the introduction of air, would be very undesirable. And a serious difficulty in the way of the use of compressed gas alone is that its sulphur content is commonly so high that the compressors are ruined in a few months.

NATURAL-GAS GASOLINE PLANTS

Nine natural-gas gasoline plants have been installed in the Clark County field. The largest produces from 1,000 to 1,500 gallons per day, but the others are mostly small—about 150 to 200 gallons per day. These smaller plants would have a potential capacity of about 400 gallons per day if the supply of gas were sufficient.

Recovery

NORMAL DECLINE

The normal decline in production of the average well in the Clark County field cannot be estimated with much accuracy, because the introduction of the vacuum pump, deepening of existing wells to lower pays, as well as other factors, have combined to offset the normal decline to an unknown extent. Some idea of the decline may be gained, however, from the following data:

From an average initial production of 50 barrels after shooting the average well in this field declined within two weeks to probably less than 10 barrels per day. Approximately 645 wells, or about 12.4 per cent of the total number had declined to the point of abandonment by 1920 (that is, in 13 years or less), but in general these were edge wells, or wells that for some other reason were originally small producers. The average well of the field settled in 13 years to 1.1 barrels per day.

Clearly, however, the decline would have been greater if it had not been for the introduction of the vacuum pump and compressed air, the deepening of the wells to lower pays and the successful handling of water.

RECOVERY TO DATE

Table 2 gives the average recovery per acre to date for the individual pools and for the Clark County field as a whole. The averages were obtained by "charging up" to the total production not only the actually productive acreage but also considerable acreage from which no oil or but a small quantity has been pumped, or from which only gas has been obtained. Locally production has been obtained from two definitely separated sand horizons, but the acreage for which this holds true is too small to alter the figure materially. Because of the inclusion of the considerable but undetermined amount of non-productive acreage, the average recovery figure per acre of 2,630 barrels for the field as a whole, as well as the pool averages, is doubtless too low. Indeed, in parts of the field the actual recovery per acre has more than doubled this figure; and in general the actual recovery from individual leases varies widely from the field average above stated. However, in spite of its inexactness, the figure is nevertheless rather reliable in predicting recoveries in territory producing from similar sands.

AMOUNT OF OIL REMAINING

To estimate the amount of oil remaining in a sand with even a small degree of accuracy is a difficult task at best. In the Clark County field the sands are so irregular and vary so in porosity, saturation, and thickness of true pay from place to place, that the task is impossible with the data available. Until many drill cores are taken, even rough estimates cannot be made with any confidence.

This subject will be considered in more detail in Chapter IV in the discussion of the use of logs, cuttings, and cores for determining sand conditions.

GEOLOGY

Introduction

The geology of the area is considerably more complex both stratigraphically and structurally than that of many other parts of Illinois. And so closely are the nature and causes of these complexities related to the location of oil and gas pools, that it was necessary to work out the geology of the area in all possible detail.

The structural studies, especially, were handicapped by the scarcity of outcrops, a condition due in part to the prairie nature of the area, and in part to the prevalence of glacial moraine, covering bed rock. The report is based to a large extent on sub-surface data, principally churn-drill logs. Although such data leave much to be desired, they proved sufficient for the determination of both regional structure and detailed structure in the vicinity of the producing pools, as well as regional and local stratigraphy.

The following summary aims to present as simply as possible the major geologic features of the area and their interrelation, and to make easier the reading of the subsequent detailed chapters.

Stratigraphic and Structural Relations

Plates I to VII inclusive, Plate XXI, and Tables 4 and 5, studied in relation to each other, illustrate the broad regional structure and stratigraphy of the area. The stratigraphic and structural relations will be stated with reference to these illustrations and tables.

Plate II—a longitudinal section from Lawrence County on the south to Coles County on the north—shows in a very general way the succession, the nature, the relationships and the "lay" of the rock strata which underlie the area. Examination of this section reveals that the Ordovician, Silurian, and Devonian systems underlie the entire area; that these strata are most deeply buried in Lawrence County; and that northward from Lawrence County they lie progressively nearer to the surface. The section shows also that the overlying Mississippian and Pennsylvanian systems rise similarly northward, but that some of their formations do not persist throughout the area. Along the line of the section, for example, although the lower formations of the Lower Mississippian continue north even beyond Coles County, the Spergen (Salem) is truncated in the northern part of Coles County, the St. Louis in the northern part of Clark County, and the Ste. Genevieve, the Chester, and the Pottsville in southern Clark County; the Carbondale, next above the Pottsville, laps somewhat beyond the northern edge of the Pottsville, extending well beyond central Clark County, and the McLeansboro, next above the Carbondale, laps even farther, extending northward beyond Coles County and resting directly on Lower Mississippian

formations in the northern half of the county. Other north-south sections would reveal similar southward dip and similar conditions of truncation and overlap.

The stratigraphic relations indicated in Plate II are directly related to the sequence of geologic events which produced the structure of the area. To reduce the structure of the territory between the latitude of the Bellair pool and T. 21 N. to its simplest elements, a wedge-shaped central portion (comprising sub-areas B, C, D, H, I, J, L, M, O and P, of Plate XXI) is structurally elevated some hundreds of feet above the remainder of the area, lying to the east and to the west. The elevated portion is designated the *Bellair-Champaign uplift*, and its approximate shape and extent are shown in Plate I. The depressed area bordering the uplift on the west (sub-areas A and G, Plate XXI) is part of the great central *Illinois basin* (Plate I); and the less extensive but nevertheless pronounced basin bordering the uplift on the east (sub-areas E, K, and N, Plate XXI) and extending approximately to the Illinois-Indiana state line, is called the *Marshall-Sidell syncline* (Plate I).

The southward pitch of the strata involved in the Bellair-Champaign uplift and its continuation southward through Crawford and Lawrence counties (see Plate II), is simulated by the strata of the adjoining Illinois basin and Marshall-Sidell syncline.

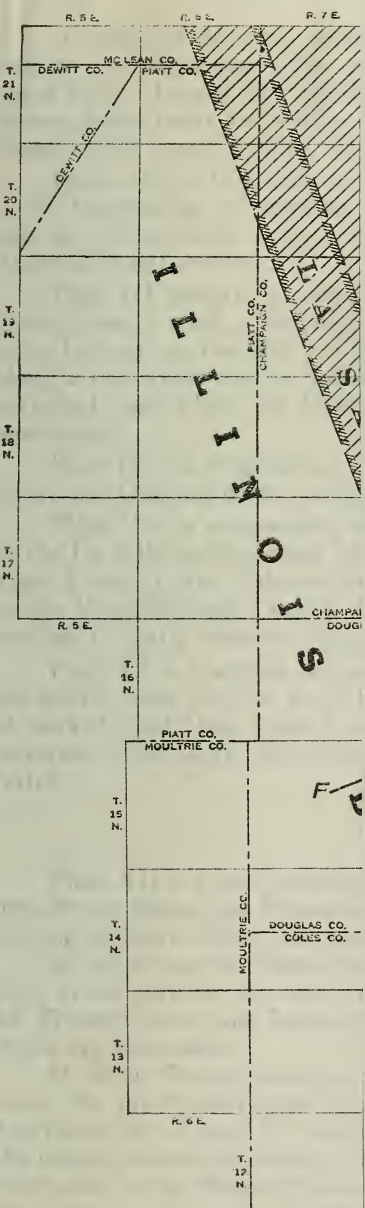
Although the western edge of the Bellair-Champaign uplift is in alignment with the La Salle anticline, the uplift is not a relatively smooth simple fold with a definite anticlinal crest, comparable to the La Salle anticline as commonly described;[6] instead, structurally it is exceedingly irregular and complicated. The available data indicate clearly that the central portion of the uplift is relatively depressed between two bordering belts or zones comprising a series of roughly aligned domes with shallow basins intervening (termed *anticlinal belts* on Plates I and XXI).

Partly because it seems possible that the western belt of aligned domes may represent the La Salle anticline and the eastern a distinct fold extending into this area from the north, the two anticlinal belts have been given individual names, the western the *La Salle anticlinal belt* and the eastern the *Oakland anticlinal belt*. (See Plates I and XXI.)

The outlines of the belts as given on Plates I and XXI are approximate only. The La Salle anticlinal belt trends south and a little east, through the southeastern corner of McLean County, and through the towns of Sadorus, Tuscola, and Hutton to the Siggins pool. The Oakland anticlinal belt trends slightly west of south from near Allerton through Newman, Brocton, Warrenton, and Kansas, to the Westfield pool. The La Salle belt may be considered either as dying out south of the Siggins pool or as merging with the Oakland belt in its continuation southward from the Westfield pool through the Casey, Martinsville, Johnson, and Bellair pools and beyond the area being considered.

Study of the structure that existed prior to Pennsylvanian time indicates that post-Lower Mississippian pre-Pennsylvanian folding took place along a series of parallel axes trending a little east of north. It is suggested that closed structures on the uplift will be found along such axes, here termed *cross-folds*. The axes or cross-folds whose existence is indicated by present data are mapped on Plate XXI. The eight cross-folds shown are not all of equal importance, and additional major and minor cross-folds probably exist.

[6]Cady, G. H., The structure of the La Salle anticline: Illinois State Geol. Survey Bull. 36, pp. 85-179, 1920.


R. 5 E.
R. 6 E.
R. 7 E.
MC LEAN CO.
DEWITT CO.
PIATT CO.
DEWITT CO.
T. 21 N.
T. 20 N.
T. 19 N.
T. 18 N.
T. 17 N.
T. 16 N.
T. 15 N.
T. 14 N.
T. 13 N.
T. 12 N.
PIATT CO.
CHAMPAIGN CO.
ILLINOIS
PIATT CO.
MOULTRIE CO.
MOULTRIE CO.
DOUGLAS CO.
COLES CO.
R. 5 E.
R. 6 E.

It should be distinctly understood that the terms *anticlinal belt* and *cross-fold* do not mean that either the belts or the cross-folds are continuous anticlinal folds. Instead they should be considered as the trends within which the known domes occur and within or very near which it seems probable that other domes which future drilling may reveal will be located.

Plates III to VI inclusive—east-west cross-sections roughly at right angles to the longitudinal cross-section, Plate II—picture the Bellair-Champaign uplift and its two anticlinal belts in their relation to the adjacent Illinois basin and Marshall-Sidell syncline.

Plate III pictures a complete cross-section of the uplift and its adjoining basins, from a point a few miles southwest of Tuscola on the west to Perrysville, Indiana, on the east. It will be noted that this section crosses the uplift along a line where the La Salle anticlinal belt (logs 2, 3, 4, and 5) is sharply anticlinal; and where the Oakland belt (logs 8, 9, 10, and 11) is practically monoclinal.

Plate IV is a cross-section of the Oakland anticlinal belt north of Oakland, where the Oakland dome renders the belt markedly anticlinal.

Plate V is a cross-section through the Westfield pool. The eastern flank of the La Salle anticlinal belt and the bordering depression is shown at the west (logs 1 and 2); the Oakland anticlinal belt is represented by a decided doming in the Westfield pool (logs 2, 3, 4, 5, and 6); and the broad Marshall-Sidell syncline is clearly indicated (logs 6, 7, 8, 9, and 10).

Plate VI is a section through the Siggins and Martinsville pools, crossing the uplift where both the La Salle and the Oakland anticlinal belts have domes of marked relief (logs 2 and 3, and logs 4, 5, and 6, respectively). The marked elevation of the uplift above the Illinois basin (logs 1 and 2) is also well illustrated.

Areal Geology

Plate XII is a map showing the glacial geology of the area. Locally glacial deposits are absent and Pennsylvanian strata outcrop. Pre-Pennsylvanian strata outcrop nowhere within the area.

So far as known, Pennsylvanian strata lie immediately beneath the glacial drift in all parts of the area except the central portion of sub-area B, where all Pennsylvanian and Mississippian beds are missing and Devonian-Silurian strata are uppermost.

If all the Pennsylvanian strata could be removed, the result would approximate the pre-Pennsylvanian surface. An areal geologic map of this surface (exclusive of sub-area F) would show Devonian-Silurian strata uppermost in the central portion of sub-area B; Lower Mississippian strata uppermost everywhere else on the Bellair-Champaign uplift except in sub-area O and the southern parts of sub-areas L and P, where Chester strata would be uppermost; and Chester strata uppermost in the Marshall-Sidell syncline, the Illinois basin, and southward in Crawford and Lawrence counties, both off and on the La Salle anticline.

In general it may be said of all the Mississippian and Pennsylvanian formations that they extend farther north in the depressed portions of the area than on the uplift. This relation is well illustrated on Plate XXIV for the Upper Mississippian and for the "older Pennsylvanian," short and long black dashes representing the edges of the former and the latter respectively.

Geologic History

Plates II to VI considered together show clearly (1) the greater accentuation of structure in pre-Pennsylvanian than in Pennsylvanian strata, (2) the marked thickening of the Pennsylvanian sections both southward and basinward off the Bellair-Champaign uplift, and (3) the relatively slight variation in thickness of the Devonian-Silurian and Ordovician sections throughout the area. These and other relations to be described in later chapters indicate that the earth movements which affected the area prior to Pennsylvanian time were alternate elevation and depression of the region, practically uncomplicated by folding; but during and subsequent to Pennsylvanian time the earth movements included the periodic progressive marked folding which resulted in the Bellair-Champaign uplift, in addition to relatively simple rising and sinking.

Essentially, therefore, the history of the area may be described as consisting of alternating cycles of elevation and depression, the successive regional movements being simple in pre-Pennsylvanian time, and complicated by folding in and after Pennsylvanian time.

Whenever the area remained wholly covered by sea water for long periods, great thicknesses of sediments—derived from distant land areas or from life in the ocean and mostly of the sort that goes to make up the cleaner shales and the limestones—were deposited. Whenever the area remained wholly above the sea, erosion was everywhere active, with the result that the land surface was lowered and carved more or less deeply by streams, the uppermost limestones were more or less deeply weathered, and the exposed strata truncated to a greater or lesser extent. And whenever the area was in the process of sinking or rising, the shorelines that marked the edge of the advancing or retreating sea shifted slowly across the area; stream erosion and weathering were active on such parts of the area as lay above sea level; and sediments, chiefly sandy and muddy, were deposited in the adjacent relatively shallow off-shore waters.

During each of the several periods of simple emergence that occurred prior to the beginning of the formation of the Bellair-Champaign uplift, that is, prior to the close of Mississippian time, the strata formed during the preceding periods of submergence and deposition were truncated by erosion. On the old buried erosion surfaces the outcrop areas of the truncated formations must have taken the shape of fairly simple belts extending approximately east and west across the area. Repeated southward tilting is in general indicated by the fact that in most instances the amount of rock removed during each period of erosion increased progressively northward.

The most extreme pre-Pennsylvanian truncation was that after Devonian time, which resulted in the removal of the entire Devonian section in the northern part of the area. But this post-Devonian pre-Mississippian truncation and indeed the total amount of pre-Pennsylvanian truncation was slight compared with the truncation that occurred during and subsequent to the period of formation of the Bellair-Champaign uplift. Over considerable areas of the uplift parts or all of the Upper and Lower Mississippian beds were removed, and over lesser areas, parts or all of the Devonian and probably some Silurian beds; and in the process of their removal, the remaining beds were locally deeply weathered.

On the old buried post-Mississippian erosion surfaces (notably one in pre-Pennsylvanian time, another in mid-Pennsylvanian time)—just as on the erosion surface immediately below the glacial drift at the present time—the outcrop

areas of formations were diverted from a simple east-west course, due to the existence of the Bellair-Champaign uplift, and took the shape of roughly V- or U-shaped belts, paralleling very approximately the outlines of that uplift.

That the earth movements during Pennsylvanian time included southward tilting of the region, meant that retreats and advances of the Pennsylvanian sea were from and to the south respectively. And whenever the area was undergoing emergence or submergence, so that the shoreline lay somewhere within the area, the Bellair-Champaign uplift was a peninsula or archipelago jutting southward into the sea, controlling the direction of sea currents in the vicinity and causing the deposition of bordering bars, beaches, and spits, and outlying muds. (See Plate XXIV.) Practically all the sand and mud deposits formed during emergence must have been destroyed by the erosion to which they were soon subjected, but many of those formed at various stages during submergence were buried and preserved beneath later sediments. Such was the origin of the Pennsylvanian pay sands.

The surface of this point of land was irregular just as land surfaces are today, and hills, composed mostly of limestone, existed on it. As the point was gradually submerged younger Pennsylvanian sediments buried these hills along with the previously described older Pennsylvanian shore deposits. The buried hills are the *erosional highs* or *lime highs* of this report; and in the events just described lies the explanation of the abrupt termination of some Pennsylvanian sands against pre-Pennsylvanian or inter-Pennsylvanian erosion surfaces and the continuation of younger strata across erosional lows and highs alike.

A weathered porous *crust* was developed at the surface of the point of land as a result of the erosion of the limestones. Such is the origin of some of the most prolific Lower Mississippian lime pays.

Whence the oil and gas came and when it accumulated in these and the other "sands" of the area, are points of geologic history about which practically nothing is definitely known.

Each of the *unconformities* shown diagrammatically in Plate VII (by wavy, horizontal line) indicates a known period of uplift and erosion, followed by submergence. In addition to showing the position of each unconformity, Plate VII shows also (by wavy vertical line) the maximum known stratigraphic extent of the truncation produced during its corresponding period of erosion.

The aggregate effect of the various unconformities, the regional tilting southward, and the longitudinal and local folding of the area, was to cause great irregularity and variation from place to place in the thickness, character and depth of the various formations. The effort has been made to summarize the practical effect of the unconformities and the regional structure by (1) dividing the area into the sub-areas shown on Plate I (A, B, C, etc.), in each of which a somewhat definite set of stratigraphic conditions seems to prevail, distinguishing it from the other sub-areas; and (2) listing in Table 4 the thicknesses of the major groups of formations for each sub-area.

Oil and Gas Sands

GENERAL NATURE AND ORIGIN

The oil and gas reservoir rocks or "sands" (Table 5) are sandstone, shaly sandstone, limestone that has been dolomitized and rendered impure and porous by weathering at or near some old erosion surface, or unweathered but jointed and originally somewhat porous limestone. The sands are capped and under-

TABLE 4.—*Summary of the thicknesses of the geologic formations in each of the sub-areas outlined on Plate XXI*

Sub-area	Part of sub-area	Quaternary	Pennsylvanian	Upper Mississippian	Lower Mississippian	Devonian and Silurian	Ordovician (Maquoketa)	Approximate depth to top of Trenton	Approximate elev. of top of Trenton	Remarks
		Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	
A Min.	East edge	50	100	0	300	700	190	1340	-650	Devonian and lower formations thicken southward; remaining formations thicken chiefly westward.
A Max.	Southwest	150	1100	400	1050	800	225	3725	-2925	
B Min.	Central	150	0	0	0	725	190	1065	-335	Devonian and lower formations thicken south; rest thicken toward edges of sub-area.
B Max.	South and West edges	300	100	0	300	780	225	1705	-725	
C Min.	Western edge	100	75	0	175	700	225	1275	-525	Devonian and older formations thicken south; all others thicken toward central part and to the south.
C Max.	South central	150?	350	0	700	825	240	2265	-1525	
D Min.	North central	100	50	0	350	700	225	1425	-725	Pennsylvanian strata thicken toward edges; Mississippian toward east and south; Devonian and older formations toward south.
D Max.	South and around edges except North	200?	250	0	700	825	250	2225	-1475	
E Min.	Northeast and Northwest	50	250	0	450	675	225	1650	-1050	Devonian and older strata as above. Above Devonian, the formations thicken southward through synclinal basin; then thin eastward.
E Max.	South central	300?	800	50?	1100	825	250	3325	-2725	

F	Min.	Northeast	50	200	0	600	650	225	1725	-1125	Devonian and older strata as above. Above Devonian the formations thin to east and thicken to south.
	Max.	Southwest	200?	550	0?	1000	800	240	2790	-2100	
G	Min.	Northeast corner	100	100	0	600	775	225	1800	-1100	Devonian and older strata as above. The formations above Devonian thicken sharply at first, then gradually to west; thickest south and west.
	Max.	Southwest	200	1700	700	1500	1100	275	5475	-4775	
H	Min.	North end	50	100	0	300	800	225	1475	-825	All formations thicken southward. Data very general on this sub-area.
	Max.	South end	200?	1000?	200?	1250	875	250	3775	-3075	
I	Min.	Northwest corner	50	100	0	400	800	240	1590	-950	All formations thicken to the south. All above Devonian show thickening toward central part. Slight variation of west edge would cause large amount of thickening in upper systems.
	Max.	Southeast and south central	200?	500	0	1100	850	250	2900	-2100	
J	Min.	North central	50	200	0	500	825	250	1825	-1150	Devonian and older strata thicken to the south. Above Devonian they thicken toward edges and to the south.
	Max.	Around edges and South	150?	350	0	900	840	250	2490	-1800	
K	Min.	Northwest corner	50	250	0	650	825	250	2025	-1425	All formations thicken southward. Above the Devonian, formations thicken through central synclinal basin and then thin farther east.
	Max.	South central	200?	900	400	1200	900	250	3850	-3150	
L	Min.	Northwest	50	450	0	700?	825	250	2275	-1625	All formations thicken south. Those above Devonian thicken irregularly due to structure.
	Max.	Southwest	150?	800	150	1250	900	260	3510	-2850	

TABLE 4.—*Summary of the thicknesses of the geologic formations of each of the sub-areas outlined on Plate XXI*—Concluded

Sub-area		Part of sub-area	Quaternary	Pennsylvanian	Upper Mississippian	Lower Mississippian	Devonian and Silurian	Ordovician (Maquoketa)	Approximate depth to top of Trenton	Approximate elev. of top of Trenton	Remarks
			Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	
M	Min.	North central	50	250	0	880	835	250	2265	-1630	All formations thicken to south. Above Devonian, all thicken toward edges.
M	Max.	Southeast and West edge	150?	500	0	1150	900	260	2910	-2300	
N	Min.	Northwest corner	50	450	0	1000	835	250	2585	-2000	All formations thicken to south. Above Devonian, all thicken both east and west.
N	Max.	Southeast	200?	1200	600	1400	1100	275	4775	-4325	
O	Min.	North end	50	650	50	1100	900	260	3010	-2325	All formations thicken to south. Above Devonian, all thicken in general to west.
O	Max.	Places along West edge	200?	1250	400?	1400	975	275	4500	-3700	
P	Min.	North end	50	400	0	950	900	260	2560	-1900	All formations thicken to south. Above Devonian, all thicken toward edges.
P	Max.	South end	150?	850	400	1350	975	275	4000	-3400	
Q	Min.	North	100	800	400	1350	975	275	3900	-3300	All formations thicken to south. Above Devonian, all thicken to east and west.

TABLE 5.—(

ystem or series	Producing formation	Local nan ing "s l
nsylvanian	McLeansboro	Upper "gas" s and s County)
	Carbondale	Casey, C Siggins, foot an County) son a (Crawf rence (stra ((
	Pottsville	Some Ro ford C Bridgep tle Bu rarely rence

lain by shale or other rock of slight porosity. Most of the sands have their porosity reduced laterally either gradually or abruptly by (1) the transition of the sandstones to shale and the weathered limestones to unweathered limestone or shale, or (2) by the termination of the sandstones against old erosion surfaces. Most of the sands are of small extent.

The character and distribution of the sands are related more or less directly to the periodic earth movements which affected the area from time to time. Most of the producing Pennsylvanian sands, for example, owe their existence and position to the local relief of the pre-Pennsylvanian or some inter-Pennsylvanian erosion surface, and to the extension of higher portions of the Bellair-Champaign uplift as a point of land or archipelago far out into the Pennsylvanian sea—all the result of the late Mississippian and Pennsylvanian earth movements. And, for another example, most of the Lower Mississippian "crust" production is found where porosity was developed locally at or near the pre-Pennsylvanian surface by weathering of the oölitic, coralliferous, less resistant limestones during times of emergence and erosion.

The following tabulation classifies the various producing sands of southeastern Illinois according to the origin of their porosity.

Nature of Oil Reservoir Rocks

A. Porosity Original

Unaltered limestone........"Trenton" and Maquoketa

Unaltered sandstone and shaly sandstone
1. Nature and distribution in general unaffected by folding........Lower Mississippian (Carper sand)
Chester
2. Nature and distribution controlled by folds, etc., before their deposition........Pennsylvanian

B. Porosity Secondary

Altered limestone........Spergen-Salem (Westfield lime)
St. Louis (type Martinsville lime)
Ste. Genevieve (McClosky)
Chester
Altered impure sandstone........Chester

DEPTH AND GEOLOGIC AGE

The depth of the producing sands of the Clark County field varies from 300 to 2,300 feet, and their geologic age from Pennsylvanian to Ordovician, as shown in Table 5 and Plates II and XXIII.

RELATIVE ECONOMIC IMPORTANCE OF THE VARIOUS SANDS

The great bulk of the oil production of the field comes from Pennsylvanian strata, chiefly Carbondale and McLeansboro sands, but much comes also from Mississippian strata—chiefly from the Lower Mississippian limestone (lime pays of St. Louis and Spergen age) but also from Upper Mississippian strata (Chester sand and lime pays). Relatively unimportant quantities are contributed at present by Lower Mississippian pays of Kinderhook age (Carper sand), and by two Ordovician lime pays, the more important of Kimmswick age ("Trenton"), and the other, with but a single well, of Maquoketa age ("Clinton" sand).

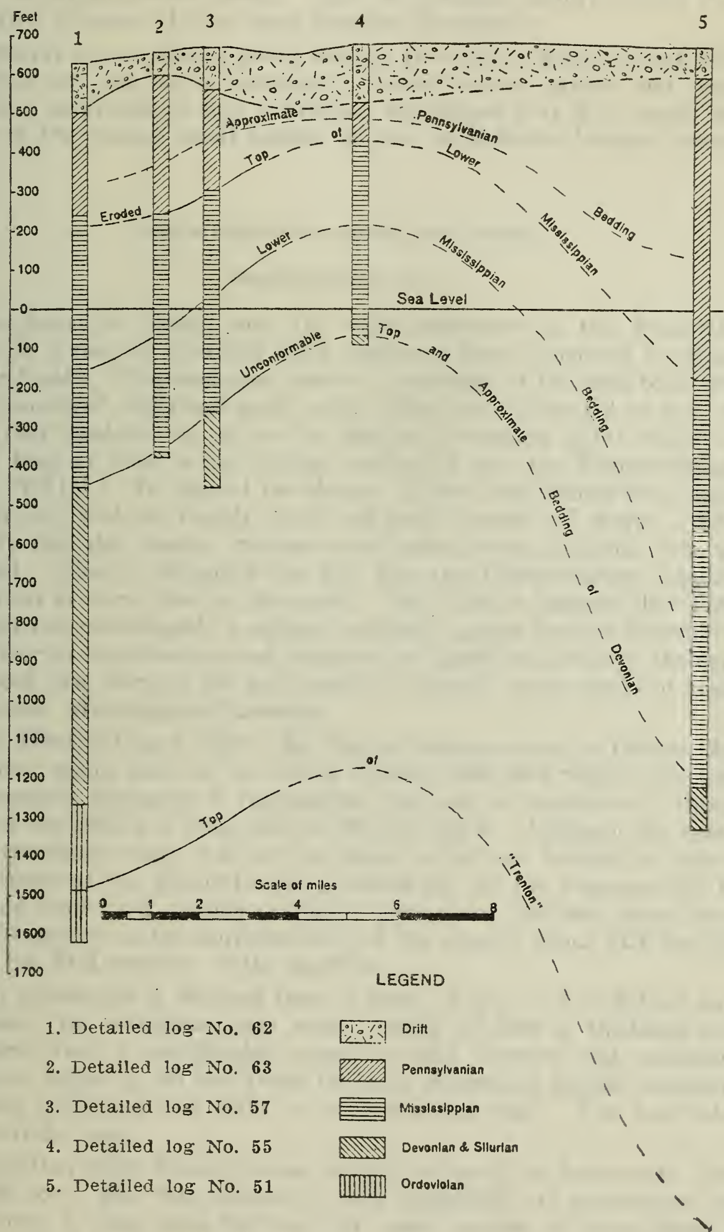
SANDS PRODUCING IN EACH POOL

In the Parker Township pool the main producing zone is in the Lower Mississippian limestone of Spergen (Salem) age. Several pays are found in the upper 200 feet of this limestone from 300 to 500 feet below the surface. A gas sand of Pennsylvanian age about 60 feet above the Lower Mississippian limestone has given some production. The upper 160 feet of the "Trenton" (Ordovician) limestone found at a depth of approximately 2,300 feet, has recently been demonstrated productive. In the Martinsville pool, most of the initial drilling found oil in the upper part of the Lower Mississippian limestone, probably of St. Louis age, at a depth of approximately 500 feet. At present the Carper sand of the basal Mississippian is being developed. The Siggins, York, Casey, and Johnson pools produce chiefly from Pennsylvanian sands at depths of from 300 to 700 feet from the surface. The Bellair pool has production from Pennsylvanian sands at depths of from 500 to 700 feet, and from Chester sands at depths of from 800 to 950 feet. Between the Bellair pool and the main Crawford County pools, most of the production comes from Pennsylvanian sands at 900 to 1,000 feet.

CONDITIONS OF PRODUCTIVITY

The pools of the Clark County field are all located on the Bellair-Champaign uplift (Plate I). Some of the production (notably the Pennsylvanian) comes from sands whose distribution is confined to the uplift or its immediate vicinity, but much of the rest of the production comes from strata represented both off and on the uplift. These relations indicate that the broad regional anticlinal condition provided by the Bellair-Champaign uplift is probably prerequisite to production.

The producing pools are in general approximately co-extensive with domes, noses, or flattenings on the uplift, making it appear that some such structural feature is also a prerequisite condition for productivity. For example, the Parker, Siggins, Martinsville, South Johnson, Vevay Park, York and Casey pools are either wholly or in part associated with well-defined domes and the Bellair, North Casey, Casey, and North Johnson pools either wholly or in part with lesser domes, warpings, or flattenings. But it must be most emphatically stated that the correspondence of the pools to these structural features does not necessarily indicate that the oil accumulated where it did directly or primarily in response to the structure. In fact, much of the production in the Clark County field is more directly and closely related to sand discontinuity than to the structure with which it is associated. As a generalization it may be said that for the Pennsylvanian and Chester production, sand discontinuity is commonly the primary factor controlling the distribution of the pools, whereas for most Lower Mississippian and older sands, many of which are commonly continuous over wide areas, doming or some such well-defined structural condition is a prerequisite for production. Despite the relatively slight importance of marked structure as a factor in oil accumulation in discontinuous sands like those of the Pennsylvanian, it is true that much of the Pennsylvanian production is found in areas of well-defined structural closure. The explanation of this close correspondence of Pennsylvanian production to domes, in many instances is that the Pennsylvanian sands originated directly or indirectly under the control of (and therefore often on or near) the domes that existed on the uplift during late Mississippian time; and that folding movements during



Structural section J-K of the Oakland dome. Log No. 1 is adjusted approximately to the line of section. The possible continuation of cross fold No. 8 may modify the eastern dips shown here. (A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.)

or after Pennsylvanian time domed the Pennsylvanian strata practically directly over the old Mississippian domes. (See the geologic history of the Pennsylvanian period, Chapter III, for more detailed discussion.)

In general in the present pools, because the sand is discontinuous, the production from any one pay is commonly of small extent, patchy, and irregular. But it is not surprising to find production continuous over wide areas, because the edges of the various small patches of pays at different horizons commonly overlap.

DESCRIPTIONS OF PRODUCING SANDS

PENNSYLVANIAN PAYS

Throughout the entire area, the most important of the Pennsylvanian pays occur in a zone of relatively thick sandstone lenses separated by shale and sandy shale breaks. This sandstone zone is a composite of the sand bars, beaches, spits, and associated muds and sandy muds which were deposited at and off the shorelines that bordered or lay on the Bellair-Champaign uplift while it was a point of land or shoal water jutting southward into the Pennsylvanian sea. (See Plate XXIV.) In general the cleaner, thicker sand bodies were deposited near a shoreline, and the muddy sands and muds farther off shore. And it is not unlikely that the cleanest, thickest sand bodies were deposited close to the highest land. Thus is explained the fact that the Pennsylvanian "sands" are found only on or very close to the uplift. And thus it happens that Pennsylvanian sands not uncommonly terminate abruptly against the pre-Pennsylvanian erosion surface in one direction and pinch out or grade into shale in the opposite direction; and that many of the best sands are located on the flanks of erosional highs of Lower Mississippian limestone.

In the Westfield pool, where the Pennsylvanian section is thinner than it is in the other major pools of the Clark County field, and where only part of the McLeansboro formation is represented, this zone of sandstone is thin; but over most of the field it is from 200 to 250 feet thick. Although the zone is a practically continuous unit, it is not restricted to any one horizon or even to a single formation of the Pennsylvanian; instead its top lies progressively lower in the section southward, passing gradually from about 200 feet above the base of the McLeansboro in the northern part of the area to about 165 feet below the base of the McLeansboro in the southern.

Locally production is obtained from as many as four or five distinct pays in the sand zone; the individual pays rarely exceed 25 feet in thickness and in that thickness have a considerable range in sand porosity and productivity. Some pays are logged as 60 feet thick, but such thicknesses include considerable comparatively tight and very light or non-producing sand. The intervals between pay streaks vary.

It is true that many Pennsylvanian sands produce oil on domes with closures of 20 to 500 feet. But that closures of such magnitude are unnecessary under some conditions, is clear from the fact that noses, terraces, or even simple flattened areas, all of less than 20-foot relief, are associated with large areas of Pennsylvanian production. Apparently the discontinuity of the pay horizons, due either to their termination against the pre-Pennsylvanian surface or to their transition laterally to shale, is sufficient in itself in many localities to permit oil accumulation in the absence of marked structure.

Plate XXIII shows diagrammatically the stratigraphic position of each of the important Pennsylvanian pay horizons, and serves also as a cross-index to the structure maps for each. Plates VIII and IX are generalized longitudinal sections showing the depth to the principal Pennsylvanian pay and its position with respect to Pennsylvanian bedding and the pre-Pennsylvanian erosion surface.

UPPER MISSISSIPPIAN (CHESTER) PAYS

The Chester strata were deposited as muds, lime oozes, and sands of varying purity, in shallow shifting seas that covered the entire area during most of Chester time. The absence of all Chester strata over the northern part of the uplift, and their presence elsewhere in the area both off and on the uplift, are due not to non-deposition in the one place and deposition in the other, but to differential erosion during the post-Chester periods of emergence when the uplift was a point of land.

In the Clark County field the Chester is productive only in the Bellair pool, where its thickness is approximately 200 to 250 feet. At least five horizons are productive, but only exceptionally are as many as three found in any one locality. The thickness of individual pay horizons rarely exceeds 25 feet and is commonly about 15 feet. Some of the pay streaks are sandstone, others oölitic or impure limestone; they are commonly 5 to 10 feet thick and of small lateral extent.

The pays tend to be confined to two distinct parts of the Chester section in the Bellair pool, and are divided arbitrarily into upper and lower pays, termed the 800-foot and the 900-foot sands respectively. Their stratigraphic position is indicated diagrammatically on Plate XXIII.

Wherever Chester pay horizons lie on the uplift, flattening or slight doming appears to be sufficient to cause oil to accumulate in them. Structural flattenings seem to have given production more commonly than domes. Plate XXXI shows the structure of Chester pays in part of the Bellair pool.

LOWER MISSISSIPPIAN PAYS

The principal Lower Mississippian pays (Martinsville and Westfield limes) lie at the top or at various horizons within 200 feet of the top of the Lower Mississippian limestone (the "Mississippi lime" of the driller).

The pay streaks are limestone beds that for one reason or another were made more porous than the adjacent limestone beds during the time Lower Mississippian strata were exposed to weathering in the pre-Pennsylvanian or Pennsylvanian time. The erosion which accompanied the weathering truncated the existing domes and folds, thus exposing many different Lower Mississippian beds to weathering. The degree of the resultant alteration and porosity varies with the kind of limestone exposed, the oölitic and coralliferous beds tending to weather more deeply and becoming more porous than the fine-grained or shaly beds.

It follows, therefore, that the marked porosity which permits oil accumulation is present chiefly or perhaps only on the uplift, for it was there that the Lower Mississippian strata were exposed to weathering longest and under conditions most favorable to development of porosity. And it follows also that the porous areas will be patchy, because the various exposed beds at or near the old erosion surface differed in their resistance to weathering and erosion;

and that for beds of equal resistance, those subjected to weathering and erosion on the higher longer-exposed land of the uplift would tend to be more porous than those on the lower parts.

The pay streaks are commonly less than 10 feet thick and where several are present they are separated by intervals of from 10 to 100 feet. In general the upper pay streaks are more prolific than lower ones unless the latter are associated with crevices, the obvious reason for the difference being that the former lay nearer the land surface for a longer time and, therefore, had greater opportunity to become more porous.

The present Lower Mississippian lime production is associated with doming and to a very minor extent with flattening on the uplift. Though porosity is essential to production and though the existence of such a condition is impossible to determine in advance of the drill, it nevertheless happens that knowledge of the structure is an aid in locating Lower Mississippian lime production, not only because of the relation of structure to accumulation, but also as an indication of the probabilities of porosity; for it was on the erosional highs of the Lower Mississippian lime that porosity was often best developed and such highs not uncommonly correspond in location with structural highs both in the Lower Mississippian strata and in the overlying beds. Plates XXVI, XXVIII, and XXIX include contours for the upper surface of the Lower Mississippian in parts of the area. Plates VIII and IX show in a very general way the position of the Lower Mississippian top in its relation to Pennsylvanian bedding.

In the lower part of the Lower Mississippian strata is the newly discovered Carper sand, which is as yet relatively unimportant but gives promise of importance in the near future. It is of Kinderhook age and is a fine-grained, shaly sandstone more than 65 feet thick lying just above the basal Mississippian (Sweetland Creek) shale. The Carper pay is apparently less porous than most of the sandstone pays of the field. It probably underlies the entire area.

Doming is believed to be a requisite structural condition for oil accumulation in the Carper sand.

DEVONIAN PAYS

At two horizons in the Devonian, one a cherty dolomitic sandstone of Hamilton age and the other dolomitic, siliceous, coralliferous limestone of Onondaga age, gas and oil shows have been found in the area. In both instances the porosity which permitted the gas and oil to accumulate, like that of the Lower Mississippian pays, resulted from weathering at or very near an old erosion surface. Such a "crust" is believed to exist generally at the eroded top of the Devonian wherever the system is present in the area, but, depending largely on the original nature of the rock, the degree of porosity varies from place to place.

Doming on the uplift is considered necessary for oil production from either Devonian pay horizon.

ORDOVICIAN PAYS

In Clark County a single small well in the "Clinton" (a lime pay in the Maquoketa), and twelve wells in the "Trenton" (another lime pay, in the Kimmswick formation), at present produce from the Ordovician.

The "Clinton" sand is a limestone zone commonly about 30 feet thick, lying in the middle part of the Maquoketa. This zone is believed to be present over all but the extreme southern part of the area, where it is replaced by shale.

The "Trenton" sand is the somewhat crystalline, calcareous, Kimmswick limestone, in places slightly sandy, found underlying the entire area with a thickness of about 160 feet.

Neither the "Clinton" nor the "Trenton" has had its original porosity increased by weathering as had the Lower Mississippian lime pays. Their porosity is due to original crystallinity and probably to jointing. In consequence both "Clinton" and "Trenton" commonly may be expected to be comparatively tight.

Sufficient data for structure contour maps of the "Trenton" were not available for most of the area. Plate XXVI shows the lay of the formation in part of the Parker pool.

Doming on the uplift is requisite for production in both "Clinton" and "Trenton."

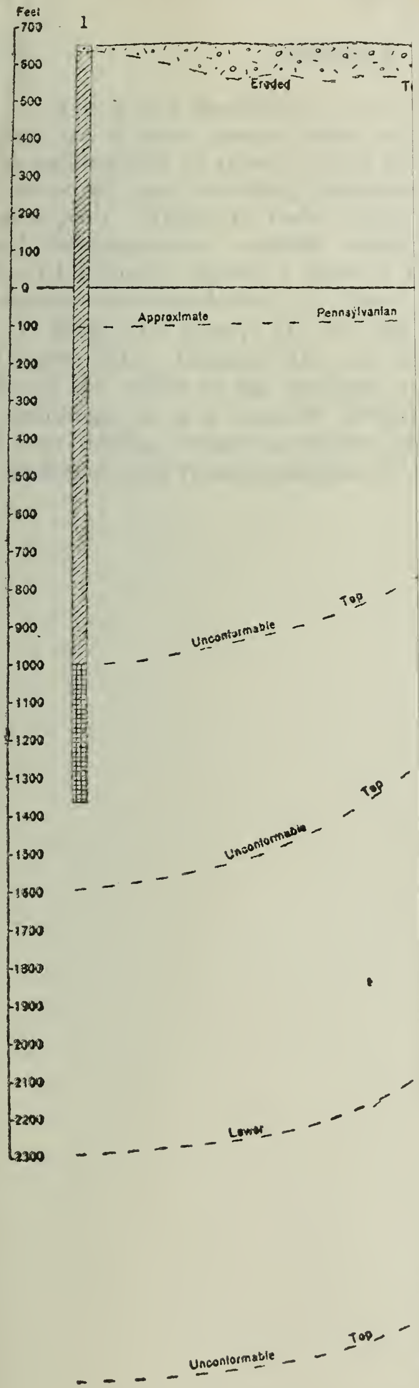
LOGGED THICKNESS OF PAY

The logged thickness of "sand"—to which the thickness of pay is more or less directly proportionate—varies greatly in the Clark County field varying from less than 5 to over 100 feet. The average logged pay thicknesses for the pools and the field are given in Table 2. The "Trenton" at Westfield is the thickest pay known; there a 140-foot thickness has continuously shown oil.

The yield of a well has no direct relation to the thickness of the pay. In fact in a given locality, the thicker the pay logged, commonly the poorer the well, for the reason that the better wells go shorter distances into the sand to obtain sufficient supply of oil than do the poor wells, for the latter attempt, but commonly fail, to procure an equivalent amount of oil by penetrating greater thickness of sand.

The best wells in the field had pay thicknesses considerably below the field average of 33 feet. For example the lower Partlow sand (Johnson) and the 900-foot sand (Bellair) gave the biggest wells in this area, yet the average thickness of pay logged was only about 15 feet for the former and about 18 feet for the latter; and in each instance the thickness of the most porous part of the pay was considerably less.

To emphasize further the fact that the pay thickness is not necessarily proportionate to the yield, the following striking comparisons are drawn: A McClosky well, Jett No. 14, sec. 14, Denison Township, Lawrence County, with a pay thickness of only 1⅓ to 1½ feet (as rather definitely established by the presence of shale and limestone above and massive, barren limestone above and below), started off at 300 barrels a day natural, and at the end of two years still gave a natural production of about 16 barrels per day; whereas many wells in the Pennsylvanian sands with from 30 to 100 feet of pay, so-called, started off considerably below the average initial production of the field (50 barrels after shooting), and are abandoned at this time when the average production per well over the field is about one barrel per day; and the "Trenton" wells with as much as 140 feet of pay, make only about 40 barrels per day after the first flush from the shot, and drop within two or three months to around 10 barrels or less per day. Summarizing it may be said that the oil sands or pays, whether Ordovician, Mississippian, or Pennsylvanian, have such varying sand conditions and such varying thicknesses of true pay that the logged thickness of sand or pay means little.



Structural section N-O through
probably flattens or has a reversal c
cause considerable deviation locally
line of section. (A set of all the d
request to the Chief, State Geologic

FUTURE POSSIBILITIES

The future possibilities of the Clark County field and the adjacent territory are of three general sorts, each of apparent importance. The first lies in improvement of recovery from already discovered pools; the second in extension of old pools, including deepening to lower pays; and the third, discovery of new pools. Efforts to realize these possibilities are of course best founded on all the information available regarding geology and operation. Chapters III to VI inclusive present a mass of such information, and Chapter VII makes definite recommendations for future prospecting.

Study of Chapters III, IV and V is not requisite to an understanding of Chapter VII. Chapters III and IV and parts of Chapter V, especially, will be of use chiefly to the geologist, either in checking for himself the writer's conclusions or as a basis for further work of his own, when new data from future drilling become available, permitting him to modify and amplify the conclusions and recommendations of this report.

CHAPTER III—GEOLOGIC DESCRIPTION OF THE AREA

INTRODUCTION

Chapter III comprises a geologic description of the area, but presupposes an understanding of the broad structural and stratigraphic relations and the geologic history already outlined in Chapter II. Terms such as "the uplift," "erosional highs," "anticlinal belts," "sub-areas," and many others already defined in Chapter II will be used here without further explanation.

TOPOGRAPHY

The area is drained by Wabash River to the east and by Embarrass River to the west. From Crawford to the southern edge of Vermilion County the divide trends approximately north and south through R. 13 W., but thence trends northwest toward Champaign in which vicinity are the headwaters of the Embarrass. The tributaries of the Wabash are much more mature than those of the Embarrass, resulting in greater surface irregularity and relief in the eastern than in the western part of the area.

On the whole, the area is rolling prairie of low relief, its elevation decreasing gradually southward from 750 to 550 feet. Even in the southern part of Clark and in Crawford County where the local relief is at its maximum, it rarely exceeds 100 feet. The maximum variation in elevation over the whole area is but about 300 feet—from 750 feet near Champaign to 450 feet in northeast Crawford County. Glacial moraines of the last glacial epoch, the Wisconsin, lie across the area from east to west as shown in Plate XII and cause the greater elevation of the northern part of the area. South of these Wisconsin moraines, the bed rock is covered by an older glacial drift, the Illinoian. These two glacial drifts are chiefly responsible for the prevalent scarcity of rock outcrops within the area.

STRATIGRAPHY

Ordovician System

INTRODUCTION

Knowledge of the distribution, character, and thickness of the Ordovician system in the area is based on study of drill cuttings and on logs of 35 drill holes,[1] all of which are located within or very near the area, and penetrated Ordovician strata. Plates II and XXV show the stratigraphic position and general character of the formations of the Ordovician.

[1]Detailed logs 1, 5, 13A, 17, 21B, 28, 35, 43, 62, 66, 65E, 85, 92, 93, 97, 107A, 107B 107C, 107D, 107E, 107F, 107G, 107H, 107I, 107J, 107K, 107L, 107O, 107P, 107Q, 108, 117, 119A, 120 and 141 located on Plate XXI. A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

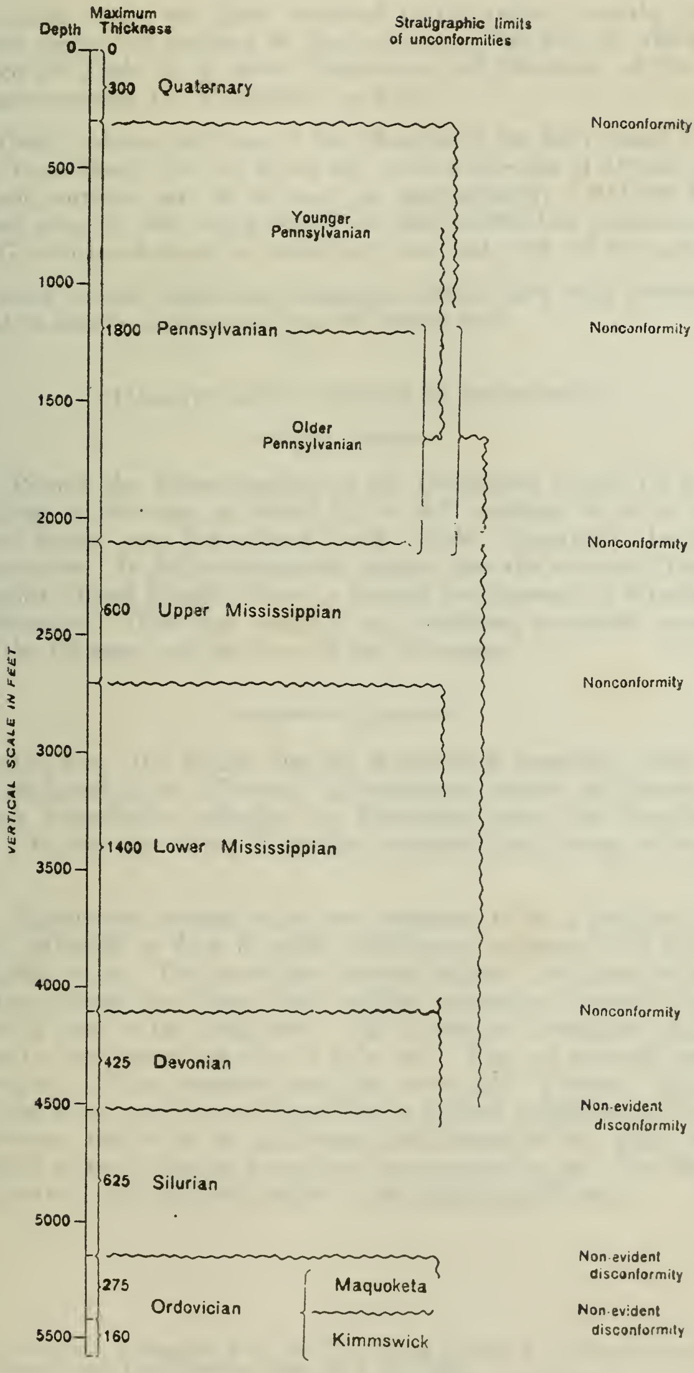


Diagram showing known unconformities and their stratigraphic extent

DISTRIBUTION

Ordovician rocks, the oldest explored in the region, underlie the whole area of this report but nowhere do they outcrop. The level at which they lie is indicated in Table 6, in which thicknesses and elevations of the topmost Ordovician formation, the Maquoketa, are given.

As Table 6 shows, the base of the Maquoketa has been found at varying elevations from about 500 feet below sea level in sub-area B (which is on the uplift in the northern part of the area), to approximately 3,900 feet below sea level in sub-area Q, and very probably to about 4,800 feet below sea level in sub-area G, which sub-areas lie respectively east and west off the uplift.

All three of the Ordovician formations which have been penetrated and recognized to date in drilling underlie the entire area.

CHARACTER AND THICKNESS OF FORMATIONS

PLATTIN LIMESTONE

The Plattin, the lowest member of the Ordovician system yet recognized from drilling in the area, is shown by its drill cuttings to be a dark gray to gray or bluish, very fine-grained, hard, brittle, lithographic, locally fossiliferous limestone. It drills considerably harder than the overlying Kimmswick. The so-called "Basal Plattin" shows a marked development of bituminous and impure limestone.[2] The data available are insufficient to permit accurate estimates of the thickness and elevation of the formation.

KIMMSWICK LIMESTONE

Directly above the Plattin lies the Kimmswick limestone which is about 160 feet thick and is the "Trenton" oil-producing horizon of Illinois. As the Kimmswick immediately underlies the Maquoketa shale, the elevations given in Table 6 for the base of the Maquoketa represent also the top of the Kimmswick.

The Kimmswick cuttings show the formation to be a medium crystalline limestone, yellowish to drab in color, fossiliferous, comparatively soft, and in places slightly sandy. The upper part is often "tighter" but from 10 feet below the top the cuttings are clear, clean, medium crystalline limestone, except for admixture of sand in the basal part. The formation is medium hard to drill, depending to some extent on size of hole, etc. The pay cuttings retain little evidence of oil. When saturated with salt water the "Trenton" drill cuttings appear bluish when wet, but on drying have a decided reddish tinge if unwashed by fresh water; this is due to the ferrous iron content of the water, which oxidizes readily to ferric iron on drying and exposure to the air. The Kimmswick cuttings contrast markedly with those of the underlying Plattin.

[2]See description of samples from well No. 29, in Udden, J. A., Some deep borings in Illinois: Illinois State Geol. Survey Bull. 24, p. 91, 1914.

TABLE 6.—*Approximate thickness and elevation of the Maquoketa formation in each of the sub-areas*

Sub-area *a*	Approximate minimum thickness	Approximate elevation of base *b*	Part of sub-area	Approximate maximum thickness	Approximate elevation of base *b*	Part of sub-area
	Feet	*Feet*		*Feet*	*Feet*	
A	190	-650	North	225	-2975	South
B	190	-350	North	225	-725	South
C	225	-525	North	240	-1525	South
D	225	-725	North	250	-1475	South
E	225	-1050	North	250	-2725	South
F	225	-1125	North	240	-2100	South
G	225	-1100	North	275	-4775	South
H	225	-825	North	250	-3075	South
I	240	-950	North	250	-2100	South
J	250	1150	*c*	250	-1800	*c*
K	250	-1425	*c*	250	-3150	*c*
L	250	-1625	North	260	-2850	South
M	250	-1630	North	260	-2300	South
N	250	-2000	North	275	-4375	South
O	260	-2325	North	275	-3700	South
P	260	-1900	North	275	-3400	South
Q	275	-3300	......	275	......	.....

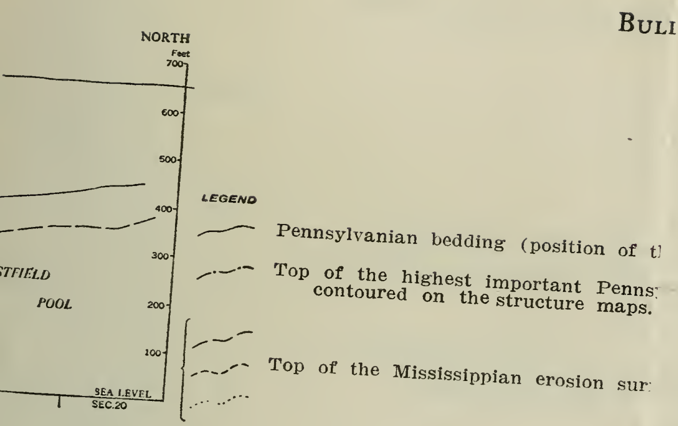
*a*For locations of sub-areas, see Plate XXI.
*b*These elevations serve also for the top of the "Trenton".
*c*See detailed logs of holes located in this sub-area. A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

Two analyses of the limestone are given below:

Analysis[3] of the "cap rock" of the "Trenton"; blown out by the shot from the O. N. Smith well No. 15, located in sec. 5, Parker Township, Clark County

	Per cent
Insoluble	.90
R_2O_3	1.20
CaO	53.97
MgO	1.54
Loss on ignition	42.32
Total	99.93

[3]Lab. No. 12079; analyst, J. M. Lindgren.


BULI
NORTH
Feet
700
600
500
400
300
200
100
SEA LEVEL
SEC.20
TFIELD
POOL
LEGEND
Pennsylvanian bedding (position of t
Top of the highest important Penns
contoured on the structure maps.
Top of the Mississippian erosion sur

T

S

whic
Chie

Ana

3

Analysis[4] of pay rock 126 feet below the top of the "Trenton"

	Per cent
Insoluble	.80
R_2O_3	.50
CaO	51.56
MgO	3.57
Loss on ignition	42.73
Total	99.16

The above analyses—the first of a sample from the top of the Kimmswick where little oil is shown, the other, from the best pay horizon—illustrate approximately the range in MgO content of this limestone.

MAQUOKETA SHALE

The Maquoketa formation, next above the Kimmswick, like the Maquoketa exposed in Kankakee and Will counties[5] is a shale horizon of fairly regular thickness averaging about 250 feet, with persistent limestone beds of varying thickness in its middle part. Cuttings of the upper 100 feet of the Maquoketa show it to be shale, somewhat dolomitic and calcareous, fine grained, greenish-blue to gray in color, hard and rather brittle, commonly containing greenish sand. The shale is non-fissile, but cleavage parallel to the bedding is observable in the cuttings. Fragments of bryozoans may also be seen in the cuttings. Toward the base of this phase, irregular shaly dolomitic limestone beds occur in places, grading downward into the purer and thicker persistent middle limestone strata, mentioned above.

The thickness of this middle limestone phase varies, but averages approximately 30 feet. It has shown considerable oil and gas locally and is called the "Clinton" by the Illinois drillers. The cuttings from these limestone beds are crystalline, those from the upper part bluish but those from the lower often yellowish. A few cherty particles are noticeable in the cuttings. The lower part of the Maquoketa consists of about 120 feet of shale, calcareous rather than dolomitic, but in general less limy, darker, softer, and somewhat purer, than the upper shale. Shells are less common and although the cuttings include some calcite, this calcite appears to be due to infiltration. This is especially noticeable near the base. The shale, brownish in color, drills easily, and does not cave. As its color is brownish, drillers sometimes confuse it and the Sweetland Creek "chocolate" shale, but its other characteristics are so different that the mistake may be easily avoided.

The Maquoketa varies but little in thickness (see Table 6), and but slightly in character within the area. It is about 190 feet thick near Mahomet, Champaign County, and thickens more or less gradually southward to 265 feet near Robinson, Crawford County, giving a total variation of only 75 feet in a distance of about 90 miles; and 60 feet of this variation occurs in the north half of the distance.

[4]Lab. No. 12080: analyst, J. M. Lindgren.

[5]Anderson, C. B., The artesian waters of northeastern Illinois: Illinois State Geol. Survey Bull. 34, pp. 172 and 214, 1919.

CORRELATION

PLATTIN AND OLDER FORMATIONS

Paleontological evidence for correlating the Plattin is lacking, but its lithologic character and its position below the Kimmswick are considered as affording a satisfactory correlation. The abrupt change from the fine-grained, hard, brittle limestone of the Plattin to the softer, yellowish, crystalline Kimmswick limestone permits the recognition of the top of the Plattin.

The deepest penetration below the top of the "Trenton" in this area is 619 feet,[6] the upper 160 feet of which is Kimmswick. Possibly the remaining 459 feet is Plattin and Joachim, but such a thickness is greater than that of the type Plattin and Joachim in Missouri; and further the lowest beds differ from those of the type Joachim. The conditions may indicate close relationship of this part of Illinois to the "Cincinnatian" geologic province to the east rather than to the "Ozarkia" province, to the southwest. It is thought possible that the "Stones River" or an equivalent formation at least, may exist in the lower part of the "Trenton" limestone of this area.

KIMMSWICK

The fossils, lithologic character, and position of the limestone formation which lies above the Plattin and beneath the Maquoketa, serve to correlate it satisfactorily as of Kimmswick age.

From pieces of the Kimmswick blown out by "shots" in Parker Township, Clark County, Dr. T. E. Savage identified the following fossils:

Bryozoa
Plectambonites sericeus
cf. Rafinesquina alternata
Strophomena sp.
cf. Orthis tricenaria

MAQUOKETA

Correlation of the Maquoketa formation is based largely on its stratigraphic position and on its lithologic similarity to the undoubted Maquoketa of Kankakee and Will counties, where the nearest outcrops occur. But drill cuttings may also show characteristic fossil bryozoans, or possibly fragments of brachiopods and molluscs.[7]

The top of the Maquoketa is a horizon that can be consistently and readily recognized in drill holes in this area, its position being marked by the change from the overlying limestone to characteristic, dark-colored, dolomitic shale.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

Little evidence is available regarding the stratigraphic relation of the Plattin to the Kimmswick. Though the change from the characteristic Plattin to the typical Kimmswick seems to be abrupt, the thickness of the Kimmswick is apparently uniform, and it would therefore seem that these two formations are conformable throughout the area.

[6] Udden, J. A., op. cit.

[7] For a list of the fossils from the outcropping Maquoketa near Wilmington, Illinois, see Savage, T. E., The correlation of the Maquoketa and Richmond rocks of Iowa and Illinois: Illinois State Acad. Sci. Trans., vol. 17, pp. 233-247, 1924.

The stratigraphic relations of the Maquoketa shale to the overlying Silurian strata and to the underlying Kimmswick are likewise not clear. The 75-foot variation in thickness of the Maquoketa within the area may be due in whole or in part either to unconformable relations at its base, or at its top, or to the greater development of limestone in the northern part of the area. It is evident, however, that should the variation be entirely due to unconformity, its amount is so slight as to be practically negligible. Both relations might be termed "non-evident disconformities."[8]

Plates II, III, IV, V, VI and VII illustrate the general structural rela-

CHARACTER AND THICKNESS OF STRATA

The Silurian beds, which constitute the lower part of the Silurian-Devonian unit, show a considerable degree of similarity over the whole area. Plates II and XXV indicate their nature.

The basal 250 to 300 feet of the Silurian consist of interbedded limestones varying from crystalline to impure argillaceous limestones. Color variations in the drill cuttings are very marked. Reddish and dark limestones are very common, the darker limestones being interbedded with white, yellow, and gray beds. But northward and westward the colors are decidedly less evident,

[8]Pirsson, L. V., and Schuchert, C., Textbook of Geology, Pt. 1, p. 292, 1915.

[9]See detailed logs 2, 4, 21A, 22, 29, 31, 33, 37, 38, 39, 40, 41A, 41B, 44, 45, 46, 47, 48, 51, 52, 53, 55, 56, 57, 60, 63, 64, 67, 68, 68A, 70, 74, 96, 98, 100, 112, 121 and 123 located on Plate XXI. A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Ill.

CORRELATION

PLATTIN AND OLDER FORMATIONS

Paleontological evidence for correlating the Plattin is lacking, but its lithologic character and its position below the Kimmswick are considered as affording a satisfactory correlation. The abrupt change from the fine-grained, hard, brittle limestone of the Plattin to the softer, yellowish, crystalline Kimmswick limestone permits the recognition of the top of the Plattin.

The deepest penetration below the top of the "Trenton" in this area is 619

The top of the Maquoketa is a horizon that can be consistently and readily recognized in drill holes in this area, its position being marked by the change from the overlying limestone to characteristic, dark-colored, dolomitic shale.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

Little evidence is available regarding the stratigraphic relation of the Plattin to the Kimmswick. Though the change from the characteristic Plattin to the typical Kimmswick seems to be abrupt, the thickness of the Kimmswick is apparently uniform, and it would therefore seem that these two formations are conformable throughout the area.

[6] Udden, J. A., op. cit.

[7] For a list of the fossils from the outcropping Maquoketa near Wilmington, Illinois, see Savage, T. E., The correlation of the Maquoketa and Richmond rocks of Iowa and Illinois: Illinois State Acad. Sci. Trans., vol. 17, pp. 233-247, 1924.

The stratigraphic relations of the Maquoketa shale to the overlying Silurian strata and to the underlying Kimmswick are likewise not clear. The 75-foot variation in thickness of the Maquoketa within the area may be due in whole or in part either to unconformable relations at its base, or at its top, or to the greater development of limestone in the northern part of the area. It is evident, however, that should the variation be entirely due to unconformity, its amount is so slight as to be practically negligible. Both relations might be termed "non-evident disconformities."[8]

Plates II, III, IV, V, VI and VII illustrate the general structural relation between the Kimmswick and the Maquoketa. For practical structure work in this area, the Maquoketa may be considered as though it were conformable with the Kimmswick ("Trenton"). The different elevations at which these beds occur are noted in Table 6. Details of structure are considered in the discussion of the structure of the oil pools and of the area north of the pools in Chapters VI and VII.

Silurian-Devonian Systems

INTRODUCTION

The Devonian and Silurian systems are treated as a unit in this report, as the evidence at present available for definitely separating them within the area is considered insufficient. Microscopic study of drill cuttings may eventually provide a reliable basis for their separation.

DISTRIBUTION AND THICKNESS

The unit representing the combined Silurian and Devonian systems does not appear in outcrop in the area, and is known therefore only by the drill.[9] It underlies the whole area, and in parts of sub-area B is encountered directly beneath the drift. Where the unit is thinnest it is questionable whether any part of it is Devonian. The Silurian-Devonian section, as will be seen from Table 7, varies in thickness from about 650 feet in the extreme northern part of the area to 1,100 feet in the extreme southern part; and the elevations of the base of the Silurian vary from 150 feet below sea level (sub-area B) to 4,500 feet below sea level (sub-area G). The gradual thickening southward is essentially independent of the structure of the Bellair-Champaign uplift.

CHARACTER AND THICKNESS OF STRATA

The Silurian beds, which constitute the lower part of the Silurian-Devonian unit, show a considerable degree of similarity over the whole area. Plates II and XXV indicate their nature.

The basal 250 to 300 feet of the Silurian consist of interbedded limestones varying from crystalline to impure argillaceous limestones. Color variations in the drill cuttings are very marked. Reddish and dark limestones are very common, the darker limestones being interbedded with white, yellow, and gray beds. But northward and westward the colors are decidedly less evident,

[8]Pirsson, L. V., and Schuchert, C., Textbook of Geology, Pt. 1, p. 292, 1915.

[9]See detailed logs 2, 4, 21A, 22, 29, 31, 33, 37, 38, 39, 40, 41A, 41B, 44, 45, 46, 47, 48, 51, 52, 53, 55, 56, 57, 60, 63, 64, 67, 68, 68A, 70, 74, 96, 98, 100, 112, 121 and 123 located on Plate XXI. A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Ill.

TABLE 7.—*Approximate thickness and elevation of the Silurian-Devonian systems in each of the sub-areas*

Sub-area *a*	Approximate minimum thickness	Approximate elevation of base	Part of sub-area	Approximate maximum thickness	Approximate elevation of base	Part of sub-area
	Feet	*Feet*		*Feet*	*Feet*	
A	700	-450	Northwest	800	-2800	Southwest
B	725	-150	North	780	-875	South
C	700	-325	North	825	-1375	South
D	700	-525	North	825	-1300	South
E	675	-825	North	825	-2425	South
F	650	-875	North	800	-1900	South
G	775	-875	Northwest	1100	-4500	South
H	800	-600	North	875	-2875	South
I	800	-700	Northwest	850	-1950	South
J	825	-750	North	840	-1600	South
K	825	-1125	Northeast	900	-3000	South
L	825	-1375	North	900	-2650	South
M	835	-1350	North	900	-2050	South
N	835	-1675	Northwest	1100	-4050	South
O	900	-2100	North	975	-3625	South
P	900	-1700	North	975	-3175	South
Q	975	-1725	North	......	......	......

*a*For locations of sub-areas, see Plate XXI.

the darker colored and impure beds being less pronounced; northeastward and northwestward blue shales and blue shaly limestones not uncommonly replace the limes in the upper 150 feet, and the limestone of the lower 100 to 150 feet is commonly clean, light colored and crystalline.

Above the basal limestones lies a white and light pink, fine-grained limestone, about 150 feet thick, the upper portion somewhat cherty locally, the basal portion shaly in the northwestern part of the area. It does not drill particularly hard. The 150-foot white and pink limestone is overlain by about 175 feet of white, cherty, siliceous dolomite, the top of which may possibly be the top of the Silurian. It drills very hard and usually cuts the bits.

The association outlined above of distinctive, thick, essentially white, dolomite (175 feet) and limestone (150 feet), underlain by colored fine-grained

limestones (250 to 300 feet) is duplicated at no other part of the Illinois rock section, and therefore constitutes a good marker for the recognition of Silurian strata.

Above this 175-foot white dolomite, which is undoubtedly Silurian, about 75 feet of rock occurs which cannot be classified confidently as either Silurian or Devonian. It is yellowish to buff-colored dolomite and limestone, with varying amounts of clean sandstone or sandy dolomite and limestone. The sand grains of this horizon are clear and well rounded not unlike St. Peter sand except for less uniformity in size. In the northern part of the area in general, the sandstone development does not seem to be confined to one definite bed; instead, the horizon, amount, and distribution of the sandstone vary to such an extent that the sandstone cannot be considered a dependable marker for separating the Devonian and Silurian accurately. However, the 75-foot thickness of yellowish dolomite with sand above the white cherty dolomite may be considered without question as transitional from undoubted Devonian to undoubted Silurian.

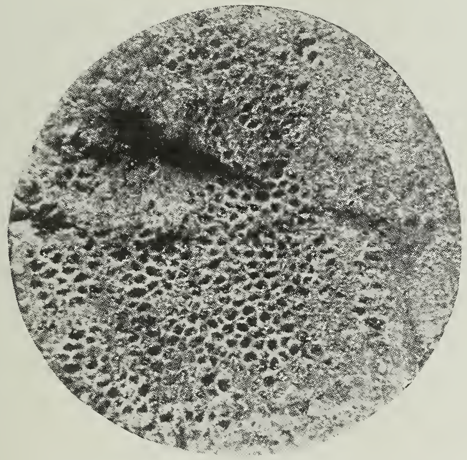


Fig. 2. Dolomitized, coralliferous Onondaga limestone; cross-section of the Hackett diamond-drill core, taken in sec. 17, T. 14 N., R. 14 W. (East Oakland Township). Magnified 1¼ times.

The Devonian beds (including arbitrarily the 75-foot thickness of transitional sandy dolomite referred to in the preceding paragraph) are locally absent and are elsewhere commonly thin in the extreme northern part of the area, but thicken southward to about 450 feet in central Crawford County. In Crawford County the Devonian is practically all limestone—slightly dolomitic and cherty at the extreme top, finer grained, impure, and crystalline below, and porous and fossiliferous toward the base. In southern Clark County and northward, the basal part of the undoubted Devonian consists of a middle sandy lime and sandstone horizon with limestone above and sandy dolomite below. In Coles and Douglas counties, a fossiliferous, porous limestone lies at or near the top of the Devonian section, the finer-grained upper lime that is uppermost farther south being absent or very thin. Near Perrysville, Indiana, (detailed log No. 28)[10] only the 75-foot transitional sandy dolomite arbitrarily considered

[10]A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

the basal part of the Devonian remains; and in the extreme northern part of the area even this questionable Devonian is missing and Mississippian (Sweetland Creek) shale caps the siliceous dolomite of the Silurian.

The Onondaga (older Devonian) drill cuttings carry an abundance of coral remains (figs. 2 and 3), and indicate that the Onondaga strata are considerably less fine grained, purer and more porous than the overlying Hamilton and still younger Devonian limestone.

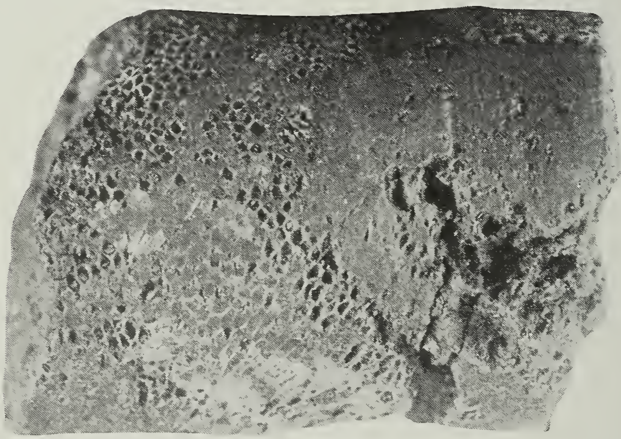


Fig. 3. Dolomitized, coralliferous Onondaga limestone; part of the Hackett diamond-drill core, taken in sec. 17, T. 14 N., R. 14 W. (East Oakland Township). Magnified about 1¼ times.

Wherever the Sweetland Creek (Mississippian) shale caps Devonian limestone, drill cuttings and cores of the upper part of the limestone show the effect of the weathering and erosion to which the area was subjected prior to Sweetland Creek times. Both cuttings and cores show dolomitization, silicification, and a resultant increase in the original porosity of the limestone for a considerable distance below its upper surface. White cherty particles, and usually some oil can be noted. But wherever the beds directly beneath the Sweetland Creek are the sandy beds transitional from the undoubted Silurian to the undoubted Devonian, they show little alteration. The degree and depth of alteration seems to be greater in the northern than in the southern part of the area, and more marked with the coral beds of the Onondaga (figs. 2 and 3) than with the crystalline or fine-grained beds of the younger Devonian formations. Even when the Onondaga lies some distance below the old erosion surface at the top of the Devonian, the cuttings may show small amounts of oil. Below are analyses of two samples of Devonian limestone, one taken close to the erosion surface, the other 10 feet lower. The greater alteration of the upper sample is apparent.

Analyses[11] of Devonian limestone cored in sec. 17, E. Oakland Township, Coles County.

Sample taken 5 feet below the base of the Mississippian (Sweetland Creek) shale; limestone recrystallized and oil-soaked.

	Per cent
Insoluble	6.75
R_2O_3	2.40
CaO	29.31
MgO	15.49
Loss on ignition	43.44
SO_3	.70
Alkali { Na_2O, K_2O	2.32
Total	100.41

Sample taken 15 feet below the base of the shale and 3 to 4 feet below the oil-soaked portion of the core.

Insoluble	2.50
R_2O_3	.90
CaO	47.02
MgO	7.24
Loss on ignition	42.69
Total	100.35

In the core from the Goff farm (detailed log No. 44)[12] just west of Camargo, Douglas County, an unusually great thickness of Devonian limestone showed intense silicification throughout and extreme porosity at some horizons. The fossils could not be identified, but it is believed that most of the Hamilton and all the Onondaga were penetrated. As the Hamilton and possibly the Onondaga strata are known to underlie immediately the drift near Pesotum only a few miles farther north, it would seem that these Devonian beds are probably readily accessible to surface waters in the vicinity of Camargo, thus explaining their extreme alteration as exhibited in the Goff core.

CORRELATION

SILURIAN

Identification of the top of the Maquoketa is readily made on the basis of its typical, marked, lithologic characteristics. But the slight degree of unconformity between the Silurian and the Ordovician, and the lack of conclusive paleontological evidence make it uncertain whether the top of the Maquoketa is also the base of the Silurian or whether still younger Ordovician strata intervene between the Maquoketa and the Silurian. Thus, exact identification of the Ordovician-Silurian contact is problematical.

But the similarity of the outcropping Alexandrian (that is, lower Silurian) beds of Kankakee and Will counties, near Channahon and near Custer Park,[13] to the strata directly above the Maquoketa in the area of this report makes it seem reasonable to accept the latter as Silurian also, and therefore to consider

11Lab. Nos. 12077 and 12078. Analyst, J. M. Lindgren.

12A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

13Savage, T. E., Stratigraphy and paleontology of the Alexandrian series in Illinois and Missouri: Illinois State Geol. Survey Bull. 23, pp. 67-94, 1917.

the top of the Maquoketa as the base of the Silurian in this area. Above these basal beds, which are approximately 250 feet thick, at least 150 feet seems to correspond to the Brassfield[14] with which the Clinton of Ohio corresponds. The Brassfield is, in part at least, equivalent to the Sexton Creek limestone, which is the highest formation of the Alexandrian series. Above the Alexandrian strata lies the Niagaran, about 300 feet thick.

DEVONIAN

From drill cores taken in the area of this report, Dr. T. E. Savage has identified the following typical Devonian fauna, thus definitely establishing the Devonian age of the strata:

Hamilton fauna

Chonetes coronata
Tropidoleptus carinatus

Onondaga fauna

Cyathophyllum rugosum
Cladopora expatiata
Spirifer varicosus
Proetus crassimarginatus

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The stratigraphic relation of the Maquoketa shale with the overlying Silurian is non-evident disconformity.

The stratigraphic relations at the top of the Silurian are not known definitely, but, judging from the regularity of the sequence and type of the Silurian beds, if an unconformity exists, it is probably slight. Indeed, the regularity of the Silurian formations might be taken as definitely indicating conformable relations, if it were not for the following considerations: (1) if the base of the 75-foot transitional sandy yellow dolomite, arbitrarily considered as basal Devonian in previous paragraphs, is actually the base of the Devonian, then that system seems to rest with slight unconformity on the Silurian; (2) the alteration of the undoubted Silurian beds and the irregular development of sands and sandy lime above them suggest the possibility of an unconformity; and (3) a lesser development of sand combined with a persistence of Hamilton limestone in the northwest part of the area, suggests the possibility of an overlap. In the light of present knowledge, the relationship of the Silurian and Devonian may, perhaps, be best considered as a non-evident disconformity.

The top of the Devonian is distinctly unconformable with the overlying Sweetland Creek (Mississippian) shale, a relation which is manifested in a maximum variation of about 450 feet in the thickness of the Devonian between the northern and southern limits of the area. The fact that the variation is largely accounted for by the absence of an increasing number of the upper Devonian limestone beds northward from Crawford County, indicates truncation of the Devonian system and the existence of a considerable unconformity at the top of the Devonian.

The general structural relations of the Silurian and Devonian systems are illustrated in Plates II to VI, inclusive.

---

[14]Foerste, A. F., The Silurian, Devonian and Irvine formations of east-central Kentucky: Kentucky Geol. Survey Bull. 7, pp. 18, 27-35, 1906.

Within any one part of the area, for all practical purposes, the bedding of the Silurian may be considered conformable with the eroded top of the Devonian, as the error introduced by disregarding the unconformity is too slight to modify major structures noticeably. Similarly, the Devonian bedding may be considered conformable with all strata below it, including the "Trenton." The erosion of the Devonian top may also be ignored safely, and its elevations used as a basis for local structure maps, without fear of introduction of important errors.

Mississippian System

SUBDIVISION

The Mississippian system comprises two important, lithologically different series, the Lower Mississippian, and the Upper Mississippian or Chester, separated by a marked unconformity. For this reason it is permissible and desirable to describe the Lower and the Upper Mississippian separately.

LOWER MISSISSIPPIAN SERIES

DISTRIBUTION AND THICKNESS

Lower Mississippian formations do not outcrop in the area of this report, though they do occur immediately below the drift in parts of sub-area B. Knowledge of the series was therefore obtained from study of cores, drill cuttings, and many well records from the area, as well as indirectly from Lower Mississippian outcrops in Indiana east of the area. Plate II gives a very general idea of the character and relations of the Lower Mississippian formations.

As noted in Table 8 the Lower Mississippian is absent locally in sub-area B, but elsewhere underlies all parts of the area. Its thickness varies from negligible amounts in parts of sub-area B to about 1,500 feet in sub-area G; and the elevation of its base varies from 500 feet above sea level to 3,400 feet below sea level in the same sub-areas respectively. Plate XXIV includes sea-level elevations of the base of the Lower Mississippian series in several parts of the area. The type basal and lower formations are encountered throughout the area in drilling, indicating that the variation in thickness of the Lower Mississippian is due primarily to variation in thickness of the uppermost formations. These variations are attributed in part to erosion following the close of Lower Mississippian time and before the deposition of the Chester, but chiefly to erosion subsequent to post-Chester folding.

CHARACTER AND THICKNESS OF THE LOWER MISSISSIPPIAN FORMATIONS

SWEETLAND CREEK SHALE

The lowest Mississippian formation is the Sweetland Creek shale. It varies only slightly over the whole area and is readily identified by its lithological and paleontological character. It will be described in detail in the following paragraphs, but it may be said here that it underlies all parts of the area except locally in sub-area B; that at its base it is invariably chocolate or dark reddish brown shale interbedded with a minor amount of green shale; and that its thickness is about 175 feet in most parts of the area.

Table 8.—*Approximate thickness and elevation of the Lower Mississippian series in each of the sub-areas*

Sub-area *a*	Approximate minimum thickness	Approximate elevation of base *b*	Part of sub-area	Approximate maximum thickness	Approximate elevation of base *b*	Part of sub-area
	Feet	*Feet*		*Feet*	*Feet*	
A	300	-250	Along east edge	1050	-2000	Southwest
B	0	......	Central	300*c*	-100	West edge and south
C	175	-375	North part west edge	700*d*	-550	Southeast
D	350	-175	Northwest	700	-475	Southeast
E	450	-150	Northwest	1100	-1600	South central
F	600	-225	North	1000	-1100	Southwest
G	600	-100	Extreme northeast	1500	-3400	South central
H	300	-200	Extreme north	1250	-2000	Extreme south
I	400	-100	Northwest	1100	-1100	South
J	500	-75	North	900	-750	South
K	650	-300	Northwest	1200	-2100	Southeast
L	700	-550	East	1250	-1750	Southwest
M	880	-525	North central	1150	-1150	Southeast
N	1000	-850	Northwest	1400	-2950	Southeast
O	1100	-1200	North	1400	-2650	South
P	950	-750	North	1350	-2200	South
Q	1350	-2100	....	....	....	....

*a*For locations of sub-areas, see Plate XXI.
*b*The base of the Lower Mississippian series is also the base of the Sweetland Creek shale.
*c*175 feet along most of eastern edge.
*d*Varies from 350 to 700 feet north and south along east edge.

Knowledge of the Sweetland Creek shale is based on data from drill holes in the area—in all, 9 diamond drill cores, about 30 sets of drill cuttings, and about 30 detailed logs.[15]

The variation in elevation of the base of the Sweetland Creek shale is shown in Table 8. The formation does not outcrop anywhere in the area, but does occur immediately under the drift in parts of sub-area B. It has been eroded from parts of that sub-area.

[15]See detailed logs 1, 2, 4, 5, 13A, 17, 21A, 21B, 22, 28, 31, 33, 35, 37, 38, 40, 41A, 41B, 43, 44, 45, 46, 47, 48, 51, 52, 53, 55, 56, 57, 60, 62, 64, 65E, 66, 67, 69, 70, 63, 68, 68A, 74, 85, 92, 93, 96, 97, 98, 100, 103, 107A, 107C, 107G, 107Q, 107J, 107O, 107L, 107K, 107H, 107P, 107F, 107B, 107I, 107D, 107E, 108, 112, 117, 119A, 120, 121, 123 and 141, located on Plate XXI. A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Ill.

The most distinctive feature of the Sweetland Creek formation is the black-colored or *"chocolate" shale*. Green shale is present to a lesser degree, and all gradations occur interbedded, from green to slightly brown or chocolate shale to dark chocolate or black shale. Green shale, mottled by irregular bodies of chocolate, is common. The color changes are in some places gradual and in others abrupt. The thickness of individual green shale beds varies from a fraction of an inch to 8 or 10 feet.

The Sweetland Creek or "chocolate" shale horizon is an excellent key horizon because it can be easily recognized from drill cuttings. The chocolate shale drills up in pieces somewhat larger than limestone cuttings. It drills easily, but shows alternating harder and softer streaks. In general, the deeper beds seem to be somewhat harder and darker in color. The cuttings include a great amount of iron pyrite in minute crystals and in irregularly shaped masses, probably made up of small crystals.

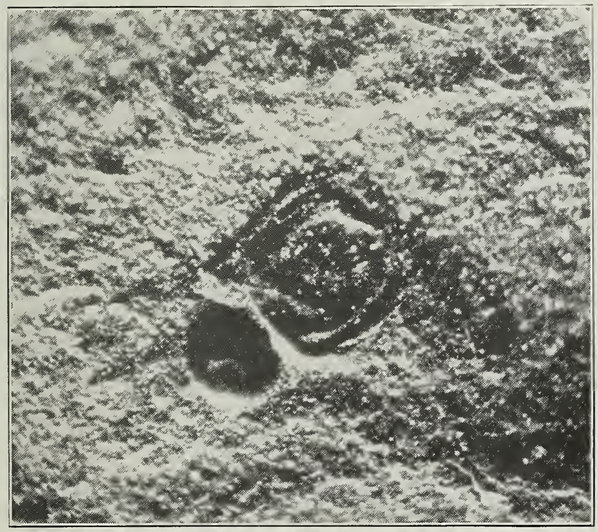


Fig. 4. Spore exines on a bedding face of Sweetland Creek ("chocolate") shale; from a diamond-drill core taken near Oakland. The larger of the two spores shown is of the thin-walled type, the smaller of the thick-walled type. Magnified about 20 times.

In all cases the drill water becomes a characteristic chocolate-red color which is very noticeable. Also a marked odor somewhat similar to that of decayed vegetable matter is always noticeable and is much stronger than the same odor noticeable in some other formations. Bubbles of organic gas or of gas produced by the pyrite appear on the surface of the water that is bailed out, as well as so-called "shale oil." Regardless of their color, the Sweetland Creek shales are very fine grained, tough, and of medium hardness, not fissile, but having a moderate amount of cleavage approximately parallel to the bedding. They do not cave and drill better and more uniformly than any other shales in the rock section.

Cuttings of the chocolate-colored shale if split along the bedding show remains of resinous-appearing spores (fig. 4), which will be described in detail

in subsequent paragraphs. The spores are most easily seen in the softer chocolate beds, because the harder beds are more difficult to split. Fragments of *Lingula* will sometimes be seen in the cuttings. In most of the beds the fragments of the spores are so small that they cannot be seen readily without a hand lens; but some beds include whole spores or spore fragments of sufficient size to permit easy recognition. The cuttings when wet commonly appear black but on drying will take on a dull chocolate color, and a broken surface becomes dull very quickly.

A determination of the oil content of a sample of the Sweetland Creek chocolate shale from the Hackett core, sec. 17, East Oakland Township, gave the following results:[16]

Oil content of a sample of Sweetland Creek chocolate shale

Gallons of oil per ton of shale	8.10
Pounds of ammonium sulphate	4.87

The oil content would be expected to vary chiefly in accordance with the color of the shale.

The thickness of the chocolate shale and the character of the rock capping it vary in different parts of the area. In Crawford County, south of the area, the drill passes from Upper Kinderhook limestone directly into chocolate shale. In the southern part of the area, a 150-foot thickness of chocolate or black to green shale is capped by greenish shale and limy shale, 50 feet of which may possibly be Sweetland Creek also, making a possible total of 200 feet. But in the central and northern parts of the area lesser thicknesses of the chocolate shale phase underlie the capping rock, the member gradually thinning northward to a minimum of 65 feet in the northern part of the area.

In Clark County the average thickness of the Sweetland Creek is only about 125 feet. There, the chocolate shale is capped by a 10- to 15-foot fine-grained, yellowish limestone, which northward passes into thinner green shaly limestone and green shale. Above this limy horizon lies 10 to 30 feet of shale, predominantly greenish in color, but in places containing brownish or light chocolate shale beds. This upper green shale includes 10 to 15 feet of soft, very fine-grained shale noted as soapstone by the drillers. An approximate analysis of the green shale from a diamond-drill core (detailed log No. 63)[17] taken in Clark County, is as follows:[18]

Analysis of green shale from the upper part of the Sweetland Creek formation

	Per cent
Silicon lioxide, SiO_2	52.80
Iron aluminum oxides, R_2O_3	27.27
Calcium oxide, CaO	1.10
Magnesium oxide, MgO	2.48
Alkalies, Na_2O	5.90
Loss on ignition	6.50
	96.05
Ferrous iron, FeO	3.45
Qualitative test for phosphorus	Positive

As the Upper Kinderhook beds of Clark County are essentially sandy shales and shales not unlike those of the upper part of the Sweetland Creek,

[16] Dept. of Chemistry, University of Illinois. Analyst, J. M. Lindgren.
[17] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.
[18] Lab. No. 13121, Dept. of Chemistry, University of Illinois. Analyst, Carter.

the first shale of the Sweetland Creek may not be easily distinguished in that locality. However, the 10- to 15-foot limestone caps the chocolate shale consistently in that county, and provides a marker that is recorded in most drillers' logs and is very noticeable in the drill cuttings.

Farther north, in Coles County and vicinity, the first Sweetland Creek beds are green shale with subordinate brown or light chocolate shale. As its color approaches a robin's egg blue which differs only slightly from the blue-gray of the overlying Kinderhook, this green shale may not contrast markedly with the Upper Kinderhook shales. However, it does show a rather different fissility and cleavage. Commonly some of the green shale beds drill very soft and are termed "soapstone," gray shale, etc., by the driller. Immediately capping the main chocolate shale member is limy shale or a hard green shale which contrasts sharply with the soft muddy shale. The drilling water from the green shale cap carries the characteristic robin's egg blue color.

UPPER KINDERHOOK FORMATION

Above the Sweetland Creek lies the Upper Kinderhook. In Crawford County it is a somewhat sandy limestone, fine grained and bluish in color, with some occurrences of shaly limestone. Northward, the Upper Kinderhook changes into shale and sandy shale, losing its calcareous content entirely, but retaining the same blue-green color. In the northwest part of the area the Upper Kinderhook shale and sandstone are cleaner than in the northeast part. It is possible that the Upper Kinderhook limestone immediately above the chocolate shale in Crawford County is the stratigraphic equivalent of the green shale and limestone which immediately cap it farther north, as noted in the description of the Sweetland Creek.

The broad regional variations in character of the Upper Kinderhook strata are briefly stated on page 111.

Analysis of a sample of Upper Kinderhook shale[19] from the core of hole No. 63 in Coles County gave the following results:

Analysis of Upper Kinderhook shale

	Per cent
Silicon dioxide, SiO_2	56.09
Iron oxide, Fe_2O_3	9.09
Aluminum oxide, Al_2O_3	21.63
Qualitative test for phosphorus	Positive

The Upper Kinderhook shales are cleaner, and the sandstones cleaner and more uniformly grained than those of the overlying Burlington. indicating better sorting of sediments. Plant impressions are common, but fossils are rare in the drill cuttings of the shales and sandy shales.

The results of Mr. C. S. Ross' examination of thin sections and powders of Kinderhook and Burlington shale and sandstone are given at the end of the following section descriptive of the Burlington, Keokuk and Warsaw formations.

The combined thickness of the Upper Kinderhook and the Sweetland Creek is tentatively considered to be from 250 to 325 feet. The Upper Kinderhook is commonly about 200 feet thick.

BURLINGTON, KEOKUK AND WARSAW FORMATIONS

Overlying the Kinderhook are the Burlington, Keokuk, and Warsaw formations, the combined group, known as the Osage, about 425 feet thick.

[19]Lab. No. 13122, Dept. of Chemistry, University of Illinois. Analyst, Carter.

In Crawford County the strata of this group are crystalline to fine-grained limestones, fossiliferous and to a slight extent shaly; fragments of crinoid stems and spirifers are noticeable in the drill cuttings. Drill cuttings rarely include chert.

In southern Clark County the basal beds are a mixture of pure and impure limestone, slightly limy to non-limy sandy shales, etc., that drill very hard locally but to the north the lower strata of the group are replaced by typically bluish sandy shale or "siltstone,"[20] with few if any limestone beds.

The upper beds of the group are commonly bluish limestone in the southern part of the area, but change northward, being replaced first by impure limes and then by siltstone of similar color. The bluish-gray color which is typical of the group where it is all limestone in the southern part of the area, is typical also of all three formations in the extreme northern part of the area where the section is entirely siltstone. This color is considered chiefly due to the presence of glauconite.

It is thought that wherever the Warsaw remains in this area, it will include some limestone beds. The Keokuk is largely shale, but farther west limestone beds are found in both the Keokuk and the Burlington, replacing some of the typical bluish-gray siltstone. Where the siltstone immediately underlies the Pennsylvanian it is sometimes impossible to establish the top of the Lower Mississippian from an ordinary log unless samples are available. The siltstone shows little porosity and wide variation in the size of the constituent grains. The sand grains are very slightly rounded and markedly angular; the amount of rounding increases with the increase in the size of the sand grain. Very large quantities of mica, some of it sericitic, little of it dark, occur commonly in the cuttings, characteristically in very small flakes; coarse mica and the yellowish mica characteristic of the Pennsylvanian shales have not been noted. Iron pyrites are also present. The drill cuttings show no marked fissility or cleavage, but do show the brittle nature of the siltstone beds. Drilling in the siltstone, though not particularly hard, is distinctly harder than in Pennsylvanian sandy shales or sandstone. The siltstone is often incorrectly logged as limestone, because limy shales and impure limestone of similar appearance are interbedded with, and drill very similarly to the siltstone beds.

A sample of the typical siltstone was analyzed[21] to determine the approximate nature of its iron content with the following results:

Analysis of Lower Mississippian siltstone

	Per cent
Ferric iron (Fe_2O_3)	2.86
Ferrous iron (FeO)	2.83

Mr. C. S. Ross[22] examined thin sections and powders of Kinderhook and Burlington shale and sandstone. The shale contains much fine, sharply angular quartz and muscovite or sericite, besides the accessory minerals, feldspar, pyrite, glauconite, magnetite, and intermediate clay-forming minerals. The glauconite

[20]The name "sandy shale" for the typical shales of the Burlington, Keokuk, and Warsaw in the northern part of the area, does not indicate their marked contrast to other sandy shales of the section which are typically alternating thin beds of clean shale and clean sandstone. The name "siltstone" is suggested as more accurately descriptive of the Lower Mississippian "sandy shales," in that they originated as an intimate mixture of relatively unsorted mud and sand, rather than as alternate thin beds of clean mud and clean sand.

[21]Lab. No. 13123, Dept. of Chemistry, University of Illinois. Analyst, Carter.

[22]Petrographer, U. S. Geological Survey, Washington, D. C.

is in finely disseminated blue-green grains that no doubt contribute largely to the blue-green color characteristic of the shale.

The sandstone has its grains better sorted; the quartz grains larger, and more of them less sharply angular; a smaller per cent of mica minerals; much less clay matter; and larger but somewhat fewer glauconite grains. The porosity is very low due to the close interlocking of the various sized grains. The sandstone included many accessory minerals which are apparently not present in Pennsylvanian sands, and the sand grains are much less rounded than those of the Pennsylvanian or Chester sandstones.

SPERGEN LIMESTONE

Overlying the Warsaw is the Spergen, a fossiliferous limestone about 200 feet thick, yellowish to buff in color, with both oölitic and fine-grained beds. Although the oölites are not as pronounced as those of the Ste. Genevieve, they occur very commonly. They are dolomitized and silicified in varying degrees wherever the Spergen has little or no capping of younger Lower or Upper Mississippian beds. Unless altered the color of this softer oölitic Spergen (which approximates the Bedford, Indiana, oölites) is a more decided drab than that of the St. Louis. Dr. T. E. Savage has often recognized *Endothyra baileyi* in Spergen drill cuttings.

ST. LOUIS LIMESTONE

Overlying the Spergen is the St. Louis formation, a hard, fine-grained, yellowish to buff or light gray, somewhat fossiliferous limestone, approximately 300 feet thick. Where the Chester does not cap the St. Louis, its eroded upper surface is characterized by typical "pot hole" (actually sink or cave) weathering and porosity. Some subordinate coarsely crystalline, oölitic beds occur rarely. The brecciated appearance of some St. Louis limestone is sometimes recognizable in drill cuttings. Dr. T. E. Savage has recognized fragments of *Lithostrotion canadensis.*

STE. GENEVIEVE LIMESTONE

Above the St. Louis in parts of the area lies the Ste. Genevieve, the youngest of the Lower Mississippian formations. Where present it varies from negligible thicknesses up to 150 feet, and is made up of interbedded fine-grained, oölitic, crystalline to fine-grained limestones, yellowish to buff in color. The oölites are readily seen in drill cuttings but are very similar to Upper Mississippian oölites. Impure sandy limestones and fine-grained, hard limestones similar to the underlying St. Louis, are interbedded here and there with the oölitic beds. Locally small amounts of sandstone are present. The base of the Ste. Genevieve is recognized by the disappearance of the oölitic beds rather than by marked contrast with the St. Louis. The characteristic fossil of the Ste. Genevieve, *Platicrinus penicillus,* to date has not been recognized in drill cuttings.

A weathered layer is invariably found at the buried upper erosional surface of the Lower Mississippian. It varies in character from place to place, probably in accord with variations in the character of the original rock.

CORRELATION OF THE SWEETLAND CREEK

INTRODUCTION

The formation considered as the base of the Mississippian system in this report, namely, the Sweetland Creek ("chocolate") shale, has in times past been considered the uppermost formation of the Devonian system, and has

been known as the "Devonian black shale." This change in correlation is so radical that it has been deemed worth while to present here a somewhat detailed discussion of the Sweetland Creek correlation problem, including all the available evidence.

The Sweetland Creek corresponds, approximately at least, to the Sweetland Creek of Iowa,[23] the Mountain Glen of Union County, Illinois,[24] the New Albany shale of Indiana,[25] the Chattanooga of Kentucky and Tennessee, and the so-called "Devonian black shale" of Missouri. Some of these shales are possibly slightly older than the shale in this area. In the extreme southern part of the area, where the overlying Upper Kinderhook is limestone, the approximate top can be readily identified, but in the central and northern parts, where the overlying Mississippian is shale, it cannot everywhere be established. The shales of the undoubted Upper Kinderhook are greenish, but in general, the shale immediately capping the chocolate shale shows a greener and less gray color than undoubted Upper Kinderhook. This horizon of change from somewhat purer green to grayish green shale is tentatively assumed to represent the top of the Sweetland Creek. In some cases the color change is not sufficiently marked to permit certain identification of the top, a fact which partially accounts for some of the variations in thickness noted in preceding paragraphs. Perhaps chemical difference between the Upper Kinderhook and the upper Sweetland Creek shale, indicated by analyses No. 13122 and No. 13121 (pp. 57 and 56) for these two shales respectively, may aid in identifying them correctly

FLORA

Many plant markings are noticeable in the cuttings of the Sweetland Creek shale, but have not been studied in detail. The most noteworthy plant remains are the spore exines (figs. 4, 5 and 6), made up of resinous-appearing bituminous matter, which gives the chocolate color to the shale. Where the exines decrease in amount, the shale becomes lighter in color. Very few exist in the green shale, although suggestions of spore impressions are found. Irregular thin fractures in the green soapstone cap are filled with reddish bituminous matter similar to the material of the spores.

These and similar spore exines were first noted by J. W. Dawson,[26] who described their occurrence near Kettle Point, Lake Huron. He named one type of spore *Sporangites huronensis,* first noted in Illinois in some boulder clays in the vicinity of Chicago.[27] Descriptions of these spores are given by Dr. George M. Dawson,[28] John William Dawson,[29] Professor J. M. Clarke,[30] Dr. Edward Orton,[31] and H. R. J. Conacher.[32]

23Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, vol. 9, pp. 289-303, 1899.

24Savage, T. E., The Devonian formations of Illinois: Am. Jour. Sci., 4th ser., vol. 49, pp. 177-178. 1920.

25Hopkins, T. C., A short description of the topography of Indiana, and of the rocks of the different geological periods: Indiana Dept. Geology and Natural Resources, Twenty-eighth Ann. Rept., p. 41, 1903.

26Dawson, J. W., On spore cases in coals: Am. Jour. Sci., 3d ser., vol. 1, p. 256, 1871.

27Johnson, H. A., and Thomas, B. W., Microscopic organisms in the boulder clays of Chicago and vicinity: Chicago Acad. Sci. Bull. 1, pp. 35-40, 1884.

28Dawson, Geo. M., On the microscopic structure of certain boulder clays and the organisms contained in them: Chicago Acad. Sci. Bull. 1, pp. 59-69, 1885.

29Dawson, John William, On rhizocarps in the Erian period in America: Chicago Acad. Sci. Bull. 1, p. 105, 1886.

30Clarke, J. M., On Devonian spores: Am. Jour. Sci. 3d ser., vol. 29, p. 284, 1885.

31Orton, Edward, A source of the bituminous matter of the black shales of Ohio: Am. Assoc. Adv. Sci Proc., vol 31, pt 2, pp. 373-384, 1883. Ohio Geol. Survey, First Ann. Rept., pp. 32-33, 1890. Geol. Report of Ohio, vol. 7, p. 26, 1893.

32Conacher, H. R. J., A study of oil shales and torbanite: Trans. Geol. Soc. Glasgow, vol. XVI, Pt. II, pp. 164-192, 1916-1917.

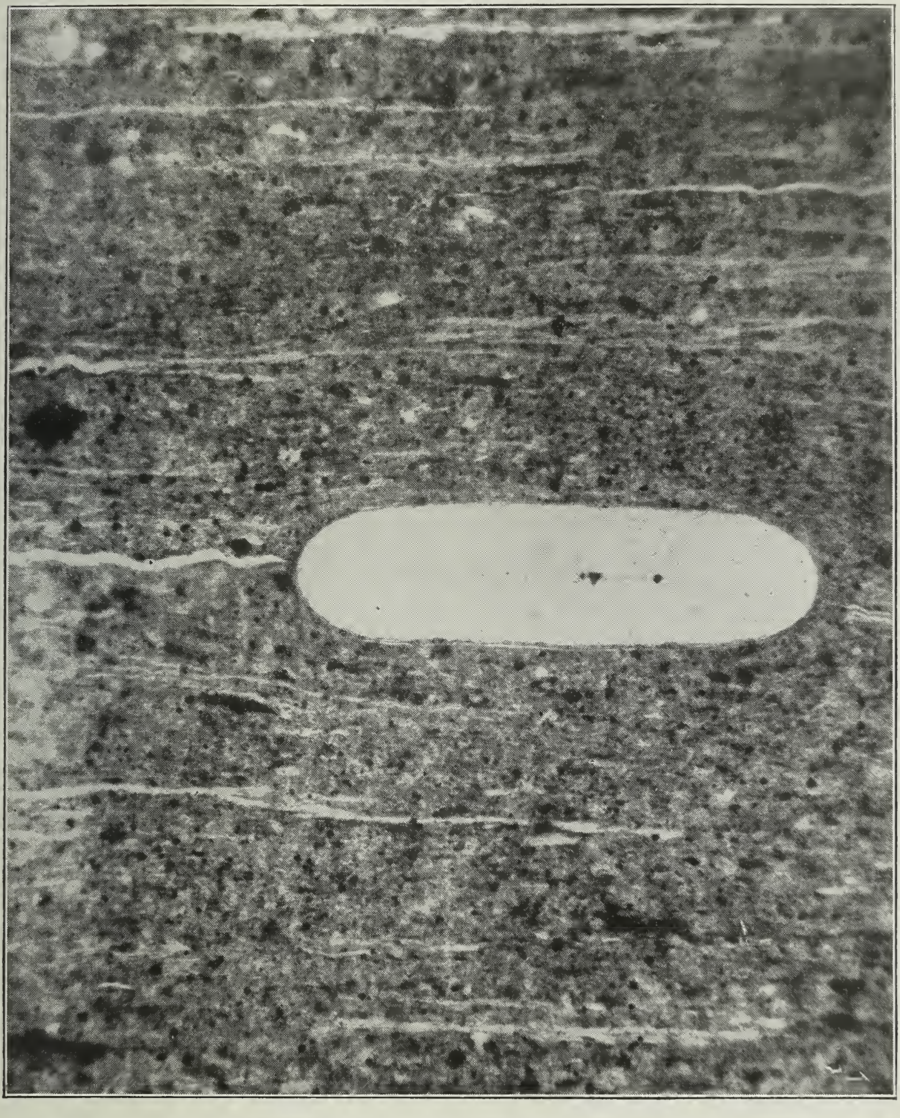


Fig 5. Microscopic vertical section of Sweetland Creek ("chocolate") shale, showing one large thick-walled spore, and many fragments of thin-walled spores. Magnified 200 times. (Photograph by Thiessen.)

The large, elongated, white oval is the large, thick-walled spore. The white lined patches are large, thin-walled spores, some of them whole, others fragmentary. The small, irregular, white dots or patches are larger particles of clay or aggregates of clay particles. The black dots are pyrite particles or aggregates of pyrite particles. The mass between the spores, clay and pyrite patches, that is the mottled, gray, embedding medium, is macerated spore matter, small spores, and finely macerated organic matter, all very intimately mixed with fine clay.

Fig. 6. Microscopic vertical section of Sweetland Creek ("chocolate") shale, showing thin-walled spores. See descriptive statement below fig. 5. Magnified 200 times. (Photograph by Thiessen.)

The latest work on the spore exines is by Dr. Reinhardt Thiessen of the U. S. Bureau of Mines.[33] Dr. Thiessen made a microscopic study of various oil shales, including the Sweetland Creek chocolate shale of Illinois; the so-called Devonian black shale of Kentucky, Indiana and Ohio; the Marcellus and Genesee shales of New York; the Green River shales of Utah; and shales from Elko, Nevada, and from Scotland. Of these shales, Dr. Thiessen found that the ones from Illinois, Kentucky, Indiana, Ohio and Scotland are all very similar in the character of their spore content.

Dr. Thiessen divides the spore exines in the Illinois Sweetland Creek shale into at least three types—two thin-walled types, and one thick-walled. Figures 5 and 6 picture microscopic sections of both thin- and thick-walled types. The thin-walled spores both whole and fragmentary make up the bulk of the spore material and are the most important factor in determining the coloring and oil content of the chocolate shale—the greater the spore content, the deeper the color and the larger the amount of oil. A determination of the oil content of a sample of the shale has already been given as part of the description of the formation on a previous page.

The spores from .5 to 1 millimeter in diameter can be recognized readily with an ordinary hand lens, and the thin-walled spores may be distinguished from the thick-walled. The larger fragments of the thin-walled spores are also discernible. The thick-walled spores are present in a sandy shale 200 feet above the Sweetland Creek shale, but the thin-walled are confined to the chocolate shale and its green shale cap. As the latter are readily recognized in ordinary drill cuttings, they serve as a reliable marker of the Sweetland Creek shale.

FAUNA

Fossil brachiopods of the genus *Lingula* are very common in the Sweetland Creek shale of Illinois. Among them, *Lingula melie* Hall and *Lingula spatulata* Hall[34] are the most common. The ratio of length to breadth in these species varies from 2:1 to 5:3. Decidedly flattened spaces are usually noticeable. In differentiating between these two *Lingulae* if the evidence of length to breadth is considered more definite or reliable than the other features, as described by Hall, then *Lingula spatulata* would seem more common. If, on the other hand, the ratio of length to breadth is not considered as reliable as other features, *Lingula melie* is more abundant. Some fish teeth (conodonts) are present in the chocolate shale.

The green cap of the Sweetland Creek bears very few fossils, but some brachiopods and pelecypods have been noted. The brachiopods were all of the genus *Orbiculoidea,* neither *Lingula melie* nor *Lingula spatulata* having been found.

COMPARISON WITH FLORA AND FAUNA OF STRATA ABOVE THE SWEETLAND CREEK

Microscopic study of drill cuttings of the Upper Kinderhook from the southern part of the area where the formation is essentially a limestone may yield paleontological data, but in the northern part of the area where the available cores were taken, the Upper Kinderhook is essentially all sandy shale with a few rather purer shale beds in which very few fossils are found. *Orbiculoideae* have been found in cuttings of the chocolate shale but are not restricted to it,

33Thiessen, Reinhardt, Origin and composition of certain oil shales: Econ. Geol., vol. 16, pp. 289-300, 1921.

34Hall, James, Natural History of New York: Pt. VI, Paleontology, vol. IV, pp. 13 and 14, Pl. I, 1867.

as Dr. T. E. Savage identified *Orbiculoidea missouriensis* in the Mississippian about 600 feet above the Sweetland Creek. The plant markings found in strata above the Sweetland Creek bear general similarity to those in the Sweetland Creek but as yet no study has been made of them. However, it is believed that the thin-walled spores are restricted to the Sweetland Creek whereas the thick-walled are known to occur as much as 200 feet above the Sweetland Creek shale.

EARLIER OPINIONS AS TO CORRELATION OF THE SWEETLAND CREEK

The chocolate or so-called "Devonian black" shales of Illinois have been definitely shown by Dr. T. E. Savage[35] to be the equivalents of the Sweetland Creek of Iowa and the formation name has been adopted from that state. Dr. J. A. Udden,[36] who first described the type occurrence of Sweetland Creek shale, correlated it as of Devonian age, and such it has long been considered. But the paleontological data now available do not bear out the Devonian correlation; though neither do they indicate conclusively that the type Sweetland Creek and its Illinois, Ohio, Kentucky, and Tennessee equivalents are of Mississippian age, for the fossils found all have a wide range through parts of both systems. The evidence presented by students of the problem from time to time is summarized briefly in the following paragraphs.

Dr. Udden[37] placed considerable emphasis on the finding of conodonts (*Ptyctodus calceolus*), which occur in an extremely thin layer at the base of the type Sweetland Creek shale. But Dr. A. O. Thomas of the Iowa State University has recently drawn the writer's attention to the fact that these conodonts were later found in beds of undoubted Mississippian age.

In the basal part of the Sweetland Creek formation, which lies unconformably on the underlying truncated Devonian limestones, fossils typical of Devonian beds younger than those upon which the Sweetland Creek is lying might be expected. Such an occurrence has been described by Dr. Grabau.[38]

Chiefly on account of the non-conclusiveness of the fossil evidence, there has been a considerable controversy over the age of the "Devonian black shales" of Ohio, Kentucky, and Tennessee. Dr. C. S. Prosser[39] presents a very thorough recapitulation and bibliography of the evidence and opinions concerning the age of the black shales in different localities. The work is especially detailed on Ohio. Dr. Newberry[40] considered the base of the Cleveland shale in Ohio as the base of the Carboniferous (Mississippian). Dr. Schuchert[41] also considered the Cleveland shale the basal formation of the Mississippian. Dr. Orton[42] identified the base of the Bedford shale of Ohio as the base of the Mississippian. Dr. Girty[43] considered the base of the Berea sandstone in Ohio as the division

---

35Savage, T. E., Devonian formations of Illinois: Am. Jour. Sci. 4th ser., vol. 49, p. 182, 1920.

36Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, vol. 9, pp. 289-303, 1899.

37Idem.

38Grabau, A. W., Types of sedimentary overlap: Bull. Geol. Soc. America, vol. 17, p. 567, 1906.

39Prosser, C. S., The Devonian and Mississippian formations of northeastern Ohio: Ohio Geol. Survey Bull. 15, 1912.

40Newberry, J. S., The Carboniferous system: Geol. Survey of Ohio Report, vol. 2, pp. 81, 92-99, 1874.

41Schuchert, Charles, Paleography of North America: Bull. Geol. Soc. America, vol. 20, p. 548, 1910.

42Orton, Edward, The Berea grit of Ohio: Am. Assoc. Adv. Sci. Proc., vol. 30, p. 170, 1882.

43Girty, G. H., The relations of some Carboniferous faunas: Washington Acad. Sci. Proc. vol. 7, p. 6, 1905. Geologic age of the Bedford shale of Ohio: New York Acad. Sci. Annals, vol. 22, pp. 295-319, 1912.

between the Devonian and Mississippian. Dr. Ulrich[44] first put the Sweetland Creek and the upper part of the Chattanooga shale in the Mississippian, considering the basal part of the Chattanooga as Devonian, but later[45] considered all the Chattanooga as Kinderhook. Dr. E. M. Kindle[46] places the base of the Carboniferous at the base of the Berea sandstone of Ohio. Dr. Prosser favors the base of the Berea as the base of the Carboniferous, but does not consider the evidence sufficient definitely to disprove Dr. Orton's assumption that the base of the Bedford is the line of separation. None of the authorities mentioned have questioned the classification of the Orangeville formation, which overlies the Berea, as Mississippian. Dr. Prosser[47] lists type sections of Sunbury shale of the Orangeville formation, noting the very abundant occurrence of *Lingula melie* Hall. Dr. Thiessen[48] has shown the contrast in the spore content of the Illinois Sweetland Creek and other shales with shales of undoubted Devonian age.

SUMMARY OF AVAILABLE EVIDENCE REGARDING CORRELATION OF THE SWEETLAND CREEK SHALE

1. The recognized Sweetland Creek fossils are no more typically Devonian than Mississippian.

2. Remains of Devonian beds younger than the Devonian beds upon which the Sweetland Creek lies have been found in the basal part of the Sweetland Creek.

3. *Lingula melie* Hall is abundant both in the Sweetland Creek of Illinois and in an undoubted Mississippian formation, the Orangeville, of Ohio and Kentucky.

4. The fossils, both plant and animal, found in the green shale cap of the Illinois Sweetland Creek, are very similar to the fossils of the overlying Mississippian shales.

5. The spore content of the Illinois Sweetland Creek and its equivalents elsewhere is different from the spore content of undoubted Devonian shales.

6. The Sweetland Creek formation rests with marked unconformity on the strata underlying it.

7. No such marked unconformity exists between the Sweetland Creek and the overlying Mississippian strata.

CONCLUSION

It is the opinion of the writer that the existing evidence favors considering the Sweetland Creek shale as of Mississippian rather than Devonian age. Thus, the Sweetland Creek should be considered the basal formation of the Mississippian in Illinois.

---

[44] Ulrich, E. O., Revision of the Paleozoic systems: Bull. Geol. Soc. America, vol. 22, pp. 281-680, 1911.

[45] Ulrich, E. O., Kinderhookian age of the Chattanoogan series: Bull. Geol. Soc. America, vol. 26, p. 96, 1915.

[46] Kindle, E. M., The stratigraphic relations of the Devonian shales of northern Ohio: Am. Jour. Sci., 4th ser., vol. 34, p. 213, 1912.

[47] Prosser, C. S., The Devonian and Mississippian formations of northeastern Ohio: Ohio Geol. Survey Bull. 15, pp. 162, 199, 219, 273, 305, 324, 325, 336, 342, 365, 374, 398, 399 and 484, 1912.

[48] Thiessen, Reinhardt, Origin and composition of certain oil shales: Econ. Geol., vol. 16, pp. 289-300, 1921.

CORRELATION OF LOWER MISSISSIPPIAN FORMATIONS ABOVE THE SWEETLAND CREEK

UPPER KINDERHOOK

In the area of this report, the Upper Kinderhook formation is correlated largely on the basis of its stratigraphic position and lithologic characteristics. Although the formation has not been described as wholly limestone before, there seems no question but that the Upper Kinderhook sandy shales of the northern part of the area are stratigraphically equivalent to the limestones overlying the Sweetland Creek shale in the southern part of the area. Where core tests have penetrated the Upper Kinderhook horizon, the nature of the strata was such as to make unlikely the presence or preservation of fossils in sufficient amount to be of value for correlation purposes. As stated in the preceding section relating to the correlation of the Sweetland Creek, the basal contact of the Upper Kinderhook is somewhat indefinite. As the top of the Kinderhook is equally indefinite, the stated average thickness of 200 feet should not be considered closely accurate.

OSAGE GROUP

The stratigraphic position and to some extent the lithologic character of the strata overlying the Upper Kinderhook, serve to correlate them as the Osage group (Burlington, Keokuk and Warsaw formations).

In the southern part of the area where the Osage is entirely limestone, the drill cuttings contain considerable crinoidal and other fossil remains, but it happens that they have no correlative value. In the absence of paleontological evidence, the marked resemblance of the upper part of the Osage to the overlying Spergen makes identification of the Osage top difficult in this part of the area.

In the northern part of the area, sandy shales are common in the Osage group, so that it is easily distinguished from the Spergen; in the Parker Township drill cuttings, for example, the contact of the Osage and overlying Spergen is obvious. But its contact with the underlying Upper Kinderhook sandy shales is not so marked.

The Osage shows the characteristic basal Mississippian blue-green color, like the Upper Kinderhook. Both the Upper Kinderhook and the Osage correspond in part at least to the Knobstone[49] of Indiana, analyses and descriptions of which are found in Indiana reports.

SPERGEN

Except in the southern part of the area, the Spergen drill cuttings are noticeably oölitic and commonly yellower than the Osage cuttings and are therefore easily distinguishable from those of the underlying Osage. The fossil *Endothyra baileyi* has been found by Dr. T. E. Savage in many undoubted Spergen drill cuttings and although it is not in itself a definite marker, its presence in beds of Spergen type may be considered as signifying that such beds are probably truly Spergen.

ST. LOUIS

The St. Louis limestone overlying the Spergen differs markedly from that formation in the type of limestone and is recognized and correlated to considerable extent on the basis of its lithologic character. The limestone is yellowish to buff-colored, fine-grained, and commonly lithographic. Dr. T. E. Savage

---

[49]Handbook of Indiana geology: Indiana Dept. of Conservation Publication 21, pp. 487-490, 1922.

has noted the presence of *Lithostrotion canadensis* in St. Louis drill cuttings from this area.

STE. GENEVIEVE

The Ste. Genevieve, overlying the St. Louis, is correlated on the basis of its stratigraphic position and its lithologic character. Its outstanding feature is the abundance of well-developed oölitic beds.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The chocolate shale of the Sweetland Creek formation lies unconformably on the eroded Devonian surface throughout all parts of the area except the northern; there the Devonian is locally entirely missing and the Sweetland Creek rests on the eroded Silurian surface.

In spite of the difficulties in determining the top of the formation, it is apparent that the Sweetland Creek is practically conformable with the overlying Upper Kinderhook. This condition at the top contrasts with the marked unconformity at the base of the Sweetland Creek. The maximum variation in thickness for the whole area is about 100 feet. It is known that the unconformity at the base is responsible for at least some of this variation.

Little is known regarding the stratigraphic relations between the other Lower Mississippian formations. Although some of them change radically in character from place to place, all the evidence points to a rather consistent thickness of the formations, indicating either conformity or slight, practically negligible unconformity.

A considerable unconformity separates the Lower Mississippian beds from younger strata, Chester beds capping Lower Mississippian formations ranging in age from Spergen to Ste. Genevieve. In any one locality the bedding of the Lower Mississippian may be considered practically conformable with the bedding of all underlying formations to and including the "Trenton," as the error that can enter in such local interpretation will be negligible in amount.

On the eroded upper surface of the Lower Mississippian lie beds varying in age from Upper Mississippian (Chester) to late Pennsylvanian, a condition signifying a great unconformity or a combination of several major unconformities at the top of the Lower Mississippian. As a result of the erosion to which it was subjected, the Lower Mississippian top is very irregular—particularly so where it is directly overlain by Pennsylvanian beds. For this reason the configuration of the Lower Mississippian top and the structure of its bedding do not conform, and it is obvious that a contour map of the top cannot be considered as picturing the structure of the bedding. It happens, however, that erosional highs on the Lower Mississippian lime were not uncommonly developed where structural highs existed, a relationship of practical importance in locating such structural highs.

UPPER MISSISSIPPIAN (CHESTER) SERIES

DISTRIBUTION AND THICKNESS

As shown by Table 9 and Plate XXIV, the Chester beds are entirely missing over all but the southern part of the Bellair-Champaign uplift, but underlie most of the remainder of the area. In general, any one bed or horizon extends farther north in the synclinal parts of the area than in the anticlinal parts, a condition resulting from the greater erosion of the structurally high parts of the area. Chester strata neither outcrop nor immediately underlie the drift

anywhere in the area, though some Chester beds do outcrop not far east in Indiana. The thickness of the Chester remnant varies from negligible amounts to 700 feet; and the elevation of the base of the Chester varies from about sea level in sub-area P to about 1,900 feet below sea level in sub-area G (Table 9).

TABLE 9.—*Approximate thickness and elevation of the Chester series in each of the sub-areas*

Sub-area [a]	Approximate minimum thickness	Approximate elevation of base	Part of sub-area	Approximate maximum thickness	Approximate elevation of base	Part of sub-area
	Feet	*Feet*		*Feet*	*Feet*	
A	0	....	Northeast and along east edge	450	-950	Southwest
B	*b*	....	....	*b*	....	....
C	*b*	....	....	*b*	....	....
D	*b*	....	....	*b*	....	....
E	0	....	....	50?	-500	Central
F	0	....	....	?	....	South
G	0	....	Northeast corner and in part along east edge	700	-1900	Southwest
H	0	....	North	200	-750	West
I	*b*	....	....	*b*	....	....
J	*b*	....	....	*b*	....	....
K	0	....	East and west sides	400	-900	South central
L	0	....	Northeast	150	-500	South
M	*b*	....	....	*b*	....	....
N	0	....	Northwest	600	-1450	Southeast
O	50	....	Extreme north	400	-1250	South
P	0	-100	Extreme north	400	-850	South
Q	400	-750	Northwest	....	....	....

*a*For locations of sub-areas, see Plate XXI.
*b*See detailed logs. A complete set of these is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

CHARACTER OF THE BEDS

GENERAL STATEMENT

In this area the Chester is essentially made up of alternating beds of shale, sandstone, and limestone, all of varying degrees of purity and of somewhat similar character throughout the series.

The shales have various colors—blue, green, brown, black and red. Most of the shales have a marked tendency to cave in a drill hole, due to very marked and irregular fissility. They are medium hard and generally pure, but locally grade to sandy shales or shaly limestones. Reddish shales (the "red rock" of the Chester) occur prominently 250 to 300 feet above the base.

The sandstones vary in purity and in the size of grains, but as a whole are more uniformly medium grained and contain less iron and mica than the Pennsylvanian sands.

Recurring limestone shells are characteristic of the Chester. The limestones include some very markedly oölitic beds.

Rarely are thicknesses of more than 30 feet of continuous limestone, 35 feet of continuous sandstone, or 40 feet of continuous shale found in the lower half of the Chester. The upper half of the Chester differs from the lower in that it includes greater amounts of shaly and sandy sediments, and lesser amounts of limestone.

Where the Chester section is 400 feet or more thick, its upper part includes a prominent thick sandstone (the Buchanan water sand of Lawrence County). It is suggested that shale replaces much of this sandstone in the northern part of Crawford County where a part of the section exists.[50] In general, however, conditions in the pools north of Lawrence County suggest that the Chester has rather a distinctive upper part which is mainly sandstone (often logged as limestone, especially when cemented) and shale, the shale increasing northward, with minor limestone members. Remnants of this upper division thin and eventually disappear northward, and locally are thicker off than on marked structures. Where this upper division is present the contact of the Pennsylvanian and Chester may not be recognized exactly from logs, but is determinable from samples of the formations on the basis of marked differences in the shales and limestones, to be described below.

From an oil-producing standpoint the middle and lower parts of the Chester are the most important.

It should be noted that, due to overlaps, the first Chester beds penetrated below the Pennsylvanian will be lower stratigraphically in holes drilled "on structure" than in those located "off structure"; and also that southward down the pitch of the uplift the Chester is thicker.

SHALES

The thickness of the middle and lower Chester shales rarely exceeds about 40 feet, but that of some of the Upper Chester shales is considerably greater. The color variation of Chester shales is very noticeable. They are greenish, bluish, brownish, and black, the colors darker than those of the younger Pennsylvanian. In the dissemination and nature of the coloring matter, and in the lesser weathering of their mineral constituents, they differ also from the Pennsylvanian shales. The resulting "sheen" of the Chester shales, as compared

[50]However, the correlation of the thick sand of the Bellair pool as entirely basal Pennsylvanian rather than in part at least as Chester, is tentative, owing to lack of exact data.

with the Pennsylvanian, is distinctive. Even the black shales of the Chester are markedly different from the black shales of the Pennsylvanian. Rarely are the Pennsylvanian shales as brittle and fissile as those of the Chester, and always their fissility or cleavage parallels the bedding, whereas the fissility of the Chester shales is developed across the bedding in irregular planes at many angles.

The Chester "red rock" is commonly garnet to even pink in shade, whereas the red shales of the Pennsylvanian are brighter red. The Chester color changes are clean-cut even when the beds of different color are thin, whereas those of the Pennsylvanian are rather irregular and patchy.

All Chester shales have a very marked tendency to spawl off when drilled through, due to the fissility crosswise of the bedding. Although the Chester shales are much tougher and as a whole are purer and drill harder than the Pennsylvanian shales, yet they spawl off and cave more. The gun-metal shale of the "older Pennsylvanian" is perhaps as tough as the Chester shales, but may be distinguished from them, as it commonly includes more iron pyrite and does not spawl off or cave as do the Chester shales. Further, none of the Chester shales duplicate the peculiar gun-metal shade of the "older Pennsylvanian" shale exactly, nor do they exhibit uniformity of color through as great thicknesses. Sandy shales occur but as a whole the shales are much cleaner and finer grained than Pennsylvanian shales.

LIMESTONES

The fact that the Chester limestones have been altered locally by truncation should be kept in mind during examination of Chester cuttings. But the remainder of this paragraph will describe, not the weathered, altered limestones, but those which still have their original character. The Chester limestones are oölitic, crystalline, and fossiliferous, commonly yellow or light in color. Their marked oölitic character is easily recognized from drill cuttings. Small fossil fragments can also be detected, but as yet no attempt has been made to work out possible characteristic fossils in the drill cuttings. In the middle and lower parts of the Chester the limestones range in thickness from thin shells to about 30 feet. The basal part of the Chester may include somewhat thicker limestone beds.

SANDSTONES

In the middle and lower parts of the Chester series, the sandstones vary from a few feet up to 35 feet in thickness. Where the upper Chester is present, some of its sandstones are considerably thicker. Truncation and resultant weathering probably account for the transition of sand beds that were apparently porous originally into non-porous limy sandstone, the pores filled with deposits of calcium carbonate. The lower Chester sands as a whole tend to become thinner as the limestones thicken. The sandstones are made up of well-rounded, well-sorted grains and are fine to medium or coarse grained. On the whole they tend toward more uniform size of grain than do the sands of the Pennsylvanian. They generally include less mica and a lack of accessory material gives them a cleaner appearance.

CORRELATION

Microscopic study of drill cuttings will possibly permit differentiation of the Chester, but in the absence of such study at the present time, attempts at correlation must be based on the succession and interval of different characteristic beds. Such correlation is adequate for any given locality, but not for separated or large parts of the area. Locally, the general character of basal or upper Ches-

ter seems fairly persistent, though individual beds may change their character abruptly within short distances. The nature of the shales, the oölitic character of the limestones, and the fossils, in addition to the general character and behavior of the formations, correlate the Chester as a whole with the typical Chester of southern Illinois[51] and the Kaskaskia of Indiana.[52]

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The Upper Mississippian (Chester) series lies unconformably on the Lower Mississippian. Possibly the Chester beds overlap the Lower Mississippian at the base with an increasing number of the lower Chester beds missing progressively northward. However, the lowermost Chester beds, in all localities where the series is represented, are somewhat similar to the type basal beds in the southern part of the area, though seemingly somewhat thinner.

As the Chester is not differentiated, relations between the different formations cannot be interpreted in detail, but conditions in the Bellair pool suggest that the beds are in conformity with each other. (See Plate XXXI.) The Chester series is unconformably overlain by the Pennsylvanian, the uppermost formations varying in age from early to late Chester. The bedding of the Upper Mississippian (Chester) can be considered conformable with the Lower Mississippian bedding in any one locality, for structural purposes. Details relating to Chester structure are discussed in the description of the Bellair pool in Chapter VI.

Pennsylvanian System

SUBDIVISION

The Pennsylvanian strata are commonly grouped into three formations, the oldest called Pottsville, the next Carbondale, and the youngest McLeansboro. The three formations are defined as follows:

The *Pottsville formation* includes all the strata from the base of the Pennsylvanian to the bottom of No. 2 (Murphysboro) coal, and varies widely in thickness up to a maximum of about 800 feet in southeastern Illinois.

The *Carbondale formation* includes all the strata from the bottom of No. 2 coal to the top of No. 6 (Herrin) coal. The maximum interval between these coals is about 375 feet in the southeastern Illinois coal basin.

The *McLeansboro formation* includes all the Pennsylvanian strata overlying No. 6 coal. The strata vary widely in thickness, the maximum of about 900 feet occurring in the deepest part of the Illinois basin.

The Pottsville, Carbondale, and McLeansboro as they are found typically in most of the remainder of the State, are lithologically dissimiliar from contemporaneous strata in the area of this report, a situation which was not realized in the past. The writer believes that consequently some of the early correlations of Pennsylvanian strata in this area, based on lithologic similarity, were incorrect, and as a result it was necessary to make an entirely new set of correlations for this report.

But the available data of the sort necessary for such recorrelation were in many instances inadequate for subdivision into Pottsville, Carbondale, and McLeansboro, and in such instances, a temporary, much less accurate subdivision

[51] Weller, Stuart, The Chester series in Illinois: Jour. Geology, vol. 28, pp. 281-303, 395-416, 1920.

[52] Handbook of Indiana geology: Indiana Dept. of Conservation Publication 21, pp. 508-515, 1922.

into "older Pennsylvanian" and "younger Pennsylvanian" had to be made. The *"older Pennsylvanian"* may be defined as the Pennsylvanian strata below the major inter-Pennsylvanian unconformity; the *"younger Pennsylvanian"* as the strata above that unconformity. The stratigraphic position of the unconformity is not the same in all parts of the area; it varies perhaps from the upper part of the Pottsville in the southern portion of the area to the lower part of the McLeansboro in the northern portion. Thus the terms "younger" and "older Pennsylvanian" are not accurate time subdivisions; but wherever existing data are insufficient for better subdivision, their use is a highly desirable and helpful alternative.

DISTRIBUTION AND THICKNESS

The distribution and thickness of the Pennsylvanian in this area are indicated in Table 10. Pennsylvanian strata are locally absent in sub-area B but present elsewhere in the area, with thicknesses varying up to about 1,700 feet. The elevation of the base of the system varies from 600 feet above sea level in sub-area B and adjoining parts of other sub-areas, to about 1,200 feet below sea level in sub-area G.

On the uplift the Pennsylvanian system is thinnest where it lies structurally highest; similarly in the areas where "younger" overlaps "older" Pennsylvanian, the latter tends to be thinnest in the structurally high localities; and further, the Pennsylvanian section is much thicker off than on the uplift. In this connection it is significant to note that a like though much less evident relationship of thickness to structure appears to exist for the Chester (see last paragraph, page 88); but that variations in thickness of the Lower Mississippian and all older systems bear comparatively little or no relationship to existing structures, except locally where such older systems were exposed to erosion at the close of Chester time or later.

OUTCROPS

GENERAL STATEMENT

Most of the known outcrops of Pennsylvanian strata in the area are of "younger Pennsylvanian" or, more specifically, of McLeansboro age. Good outcrops are so few that it is doubtful if in many localities they would assist materially in structure mapping. Pennsylvanian beds are exposed locally along the eastern side of Clark, Edgar, and Vermilion counties, and in Indiana along Wabash River and its tributaries. On the western side of the area, Embarrass River has exposed considerable Pennsylvanian rock south from T. 13 N., in Coles and Cumberland counties, where the glacial drift is thin and locally absent. North from T. 13 N., the greater thickness of glacial drift renders outcrops exceedingly rare. Worthen and Bradley[53] give some exposed rock sections which were republished in a bulletin of the Illinois State Geological Survey.

EMBARRASS RIVER OUTCROPS

An approximate section, given below, was measured along the Embarrass River valley from "The Rocks," three miles east of Charleston, in sec. 18, T. 12 N., R. 10 E., northward to T. 13 N., R. 10 E. Exposures continue south and southwest from "The Rocks" and northward into T. 13 N., but they were not visited.

---

[53] Worthen, A. H., Geology of Clark County: Geol. Survey of Illinois, vol. 6, pp. 9-21, 1875. Geology of Cumberland, Coles and Douglas counties, op. cit., pp. 98-111.
Bradley, Frank H., Geology of Vermilion County: Geol. Survey of Illinois, vol. 4, pp. 241-265, 1870. Geology of Champaign, Edgar and Ford counties, op. cit., pp. 266-275.
Sections republished by W. S. Blatchley in The petroleum industry of southeastern Illinois: Illinois State Geol. Survey Bull. 2, 1906.

BLE 10.—*Approximate thickness and elevation of the Pennsylvanian system in each of the sub-areas* ([a])

Minimum thickness	Elevation of base	Location in sub-area	Maximum thickness	Elevation of base	Location in sub-area	Remarks
Feet	*Feet*		*Feet*	*Feet*	*Feet*	
100	550	Eastern edge	1100	-500	South central	Thickens abruptly from east to west along eastern edge; thickens less abruptly to 800± feet southward along the eastern edge
0		Central	100	200	Eastern and western edges and to the south	....
75	550	Western edge	350	150	South central	....
50	525	Central	250	225	Eastern and western edges	....
250	300	Western edge	800	-450	South central	About 450 to 550 along eastern edge
200	375	Eastern edge	550?	-100	Southwest	Area extends eastward into Indiana averaging about 6 miles beyond the State line
100	500	Northeast corner	1700	-1200	South central	Thickens abruptly from east to west along eastern edge so that practically whole area has from 1000± to 1700± feet of Pennsylvanian
100	500	North end	1000?	-550	Southwest	This area least understood of those discussed
100	500	Northwest corner	500	0	Southeast	Varies from 300 to 400 feet along eastern edge
200?	425	North central	350	150	East and west edges and to south	....
250	350	Northwest corner	900	-500	South central	Varies from 250 to 300 feet along western edge
450	150	Northeast corner	800	-350	Southwest corner	....
250	300	North central	500	0	Southeast	....
450	150	Northwest	1200	-850	Southeast	....
650	-50	North	1250	-850	South	....
400	200	North	850	-450	South	....
800	-350	North	....	....	....	....

For location of sub-areas, see Plate XXI.

"slate" (the No. 6 coal horizon) are found. Locally the black shale which

** Sections republished by W. S. Blatchley in The petroleum industry of southeastern Illinois: Illinois State Geol. Survey Bull. 2, 1906.

Section measured northward along Embarrass River from "The Rocks," sec. 18, T. 12 N., R. 10 E., Coles County

		Approximate thickness Ft.	In.
14.	Sandstone, mostly massive, shaly near base, with conglomerate as basal member	40	....
	Erosional unconformity		
13.	Shale, greenish color, not sandy, clayey on weathered outcrop	1 to 25	....
12.	Limestone, nodular, dark colored, fine grained, very hard, impure	....	3
11.	Shale, greenish to dark colored	1	6
10.	Slate, black	½ to 3	....
9.	Shale, greenish; in places contains streak of black slate	4	....
8.	Sandstone, massive to platy	1	6
7.	Shale, greenish, not sandy; contains black shale streaks	35?	....
6.	Limestone, gray, platy, mostly fine-grained, fossiliferous; thin stringers of clear calcite developed in fine-grained groundmass. The following species identified by Dr. T. E. Savage are chiefly from this bed but some from bed No. 4: *Lophophyllum profundum, Productus longispinus, Productus cora, Derbya crassa, Pugnax uta, Spirifer cameratus, Spiriferina kentuckyensis, Reticularia perplexa, Dielasma bovidens, Composita argentea*	10±	....
5.	Shale, bluish, sometimes black at base	1	6
4.	Limestone, more massive than upper bed, less fossiliferous	10±	....
3.	Shale, greenish, grading to black	3	....
2.	Coal	1	....
1.	Shale	Unknown	

An erosional unconformity is apparent below the top sandstone (No. 14). At "The Rocks" on the west bank of the Embarrass this sandstone with its basal conglomerate lies about two feet above the black slate (No. 10); whereas half a mile east on the opposite bank this same sandstone with its conglomeratic base lies 25 feet above the black slate.

OUTCROPS OF GIRTYINA VENTRICOSA LIMESTONE EAST OF THE DANVILLE AREA

Near Perrysville and Silverwood, Indiana, are important outcrops of a limestone containing *Girtyina ventricosa* abundantly, which have given material help in checking correlations made for this area. These Indiana outcrops of the *Girtyina ventricosa* limestone and its associated strata are described here in considerable detail, because the bed is one of the most important horizon markers of the Pennsylvanian.

Where the *Girtyina ventricosa* limestone outcrops near Perrysville and Silverwood, Indiana, its basal 3 to 4 feet consists of rather pure, bluish, very fine-grained, hard, fossiliferous limestone containing many *Girtyina ventricosa,* besides *Chonetes mesolobus* and various other fossils not characteristic of any single horizon. The basal few inches includes a great abundance of large crinoid stems. Immediately above this *Girtyina ventricosa* horizon lies a continuous impure platy limestone about 8 feet thick, varying in color from black to blue, which passes upward in some places through purer limestone, with fusulinas, into sandy limestone and sandstone, but in most places directly into sandstone. A coal closely associated with black and green shales occurs consistently about 15 feet above the *Girtyina ventricosa* limestone, and probably another fusulina-bearing limestone lies 15 to 20 feet above the main limestone bed. Immediately below the *Girtyina ventricosa* limestone, coal and black "slate" (the No. 6 coal horizon) are found. Locally the black shale which

commonly accompanies the coal entirely replaces the coal. Elsewhere the thickness of pure coal varies from a fraction of an inch up to five feet in this general area. The approximate combined thickness of black shale and coal is about six feet. At the base of the black shale a 2-inch irregular, impure, nodular limestone caps approximately 10 feet of greenish shale. At Perrysville an impure nodular limestone two inches thick occurs about two feet below the base of the *Girtyina* limestone. Within 50 feet below the *Girtyina* limestone a third and commonly a fourth coal bed are found.

OTHER OUTCROPS

The locations of some additional outcrops are given in the following list, together with brief descriptions:

List of additional known outcrops of Pennsylvanian strata within the area of the report

Location				Description of strata
T.	R.	Sec.	Part of sec.	
Vermilion County				
19 N.	12 W.	19		Limestone
19 N.	13 W.	25	NW.	Limestone (quarry near Fairmount)
Edgar County				
12 N.	13 W.	1	SW.	Thick limestone
		11	SE.	Ten feet limestone with thinner limestones, shale, and sandstone
14 N.	11 W.	10	NE.	Ten feet limestone with other limestones, shale, and sandstone
14 N.	13 W.	12	SE.	Sandstone, shale, and thin coal
15 N.	12 W.	3	NE.	Limestone (quarry)
Coles County				
12 N.	9 E.	25	NE.	Thin limestone, shale, and sandstone; decided dip noticeable
Clark County				
9 N.	11 W.	19	SE.	Limestone
		29	SW.	Limestone
		30	SE.	Limestone
		31	NE.	Shale, etc.
9 N.	12 W.	36	SW.	
		35	SW. SE.	
		34	SW. SE.	
		4	NE.	Limestone, sandstone, and shale
		8	NW.	
		10	NE.	
		11	NW. NE.	
		12	NW. SW.	Sandstone, shale, and limestone
		17	NE.	
		22	NW.	
		23	SW.	
		26	NE.	Shale, sandstone, and limestone
9 N.	14 W.	2	SW.	
		3	SE.	
		10	SE.	
		11	NE. SW.	
		15	NW.	

List of additional known outcrops of Pennsylvanian strata—Continued

Location T.	R.	Sec.	Part of sec.	Description of strata
		16	NE.	Shale and sandstone
		8		Limestone
		21	SW.	Shale
10 N.	11 W.	19	SE.	Thick limestone
10 N.	12 W.	7	SW.	
10 N.	13 W.	12	SE.	
		14	NE.	Sandstone and shale
		11	SW.	Sandstone and coal
		8	SW.	Limestone
10 N.	14 W.	10	NE.	
		21	NW.	
		27	NW.	
		28	NE. SE.	
		29	SE.	Limestone
11 N.	10 W.	5	NW.	
		4	NW.	
		20	NW.	
		30	SE.	
11 N.	11 W.	4	SW.	Sandstone
		9	NW.	Sandstone and shale
		8	SE.	
		9	SW.	
		16	NW.	Limestone, shale, and sandstone
		18	SW.	
		19	NW.	Thick limestone
		7	NW. SW.	Thick limestone
		23	NW.	Limestone
11 N.	12 W.	2	SW.	
		12	NE. SE.	Thick limestone
		14	SW.	
		15	NW.	
		16	NE.	
		25	SW.	Sandstone and shale
		28	SW.	Limestone
		29	SW.	
		32	NW.	
		19	SW.	
		7	NW.	Sandstone and shale
		30		
		31		
		32		Sandstone
11 N.	14 W.	25	SE.	
		36	NW.	
		13	SE.	Limestone
12 N.	13 W.	27	NW.	Limestone
Cumberland County				
9 N.	9 E.	2	NW.	Thin limestone, sandstone, and shale
10 N.	9 E.	12	NE.	Ten feet limestone over sandstone
11 N.	9 E.	27		Sandstone

CHARACTER OF STRATA

GENERAL STATEMENT

The Pennsylvanian strata consist of interbedded shales, sandstones, limestones, and coals.

In general, the "older Pennsylvanian" drill cuttings are distinctly harder than those of the "younger Pennsylvanian." Some of the sandstone beds appear to be quartzitic and the sandy shales are markedly harder and more cemented than the sandy shales of the "younger Pennsylvanian." The typical gun-metal shale of the "older Pennsylvanian" is commonly associated with rather harder thin sandstone streaks. Its gun-metal blue color persists through great thicknesses, whereas in "younger Pennsylvanian" shales "color play" is typically rather marked. Like the Chester shales, the "older Pennsylvanian" shales when pure are considerably tougher in drilling than the "younger Pennsylvanian" shales. The "older Pennsylvanian" shale contains conspicuous amounts of iron pyrite, has no marked cleavage or fissility, and does not cave badly in dry open hole. The upper part of the "younger Pennsylvanian," namely that part deposited in McLeansboro time characteristically includes some thick limestones, in contrast with pre-McLeansboro "younger Pennsylvanian," from which limestones are absent or thin and commonly impure. Some limestones are included among the "older Pennsylvanian" strata also.

The characteristics of the Pennsylvanian shales, sandstones, limestones, and coals will be considered separately and in turn below.

SHALES

The Pennsylvanian shales vary widely both in purity and color. All gradations of sandiness are found, and colors range from light gray to green, bluish, brown, red, and black. In general the dark-colored Pennsylvanian shales are cleaner than the light with the notable exception of the fire clays. The thickness of individual shale members varies from a few inches up to 150 feet, the maximum thicknesses found to date being confined to the "gun-metal" blue shales. Sandy shales made up of thin distinct layers of clean shale and sandstone are very common. Such sandy shale contrasts very markedly with the sandy shale or "siltstone," of the Lower Mississippian which has its shaly and its sandy constituents intimately intermingled, rather than cleanly separated into alternating thin beds of shale and of sandstone. Shales which break with irregular fracture and have a somewhat earthy appearance are common. The sandy shales in general contain considerable mica, both coarse and fine. The sand grains are commonly of fine to medium coarseness. The grains increase in angularity with the decrease in size, but all show marked rounding. The coloring matter gives an effect of dullness, which is attributed to organic matter, although the coloring effects of oxidized pyrite and iron from the micas are noticeable in the sands and sandy shales which have very few accessory minerals remaining in unaltered state.

The clean Pennsylvanian shales are commonly very soft and drill up as mud; some of the black bituminous shales are exceptional in that they are brittle and fissile. Limy shales and shales containing carbonate nodules in all degrees of purity are very common. When subjected to wet-hole conditions, the shales, especially the impure ones, cave in open hole; but the type of "cave" is distinctly

different from the characteristic "cave" of the Chester shales in that the Chester "caves" occur in tough, generally cleaner shales of different color which have their fissility at an angle with the bedding.

The color distribution in Pennsylvanian shales might well be termed "spotty." There is usually no consistent uniformity in intensity of color or in distribution of pigment. In general the colors of the Pennsylvanian shales are not as dark as those of the Chester. Notably the red shales of the Pennsylvanian are much brighter than the so-called "red rock" of the Chester. The Chester coloring matter seems to be more finely disseminated, its mineral matter less altered. As a result, any color in the Chester has what might be described as a rather distinctive "sheen" as compared with the Pennsylvanian colors. In spite of the great variety of colors in both Pennsylvanian and Chester, rarely is a color in one system exactly duplicated in the other. Even the "gun-metal" blue shale of the "older Pennsylvanian" which, like the Chester, has its coloring matter more finely disseminated than the average Pennsylvanian shale, lacks that "sheen" characteristic of Chester shales.

Mr. C. S. Ross[54] examined powders from some "older Pennsylvanian" ("gun-metal") sandy shale and some "younger Pennsylvanian" sandy shale. The former had marked organic coloring matter and contained no glauconite; the sand grains, though subangular, were better rounded than the Mississippian sand grains; small amounts of mica were present; complete weathering of all accessory minerals had resulted in the spotty distribution of color. The latter had marked organic coloring matter, less mica, and similar weathering of accessory minerals with marked spotty distribution of color.

LIMESTONES

The Pennsylvanian limestones vary in thickness from a few inches to about 20 feet. In parts of the section beds from 5 to 20 feet thick are especially common, but rarely do more than two of them reach the maximum thickness in any single locality. They vary from relatively pure, finely to coarsely crystalline, fossiliferous and non-fossiliferous limestones, to shaly limestones or to very fine-grained, impure, hard, generally thinner, non-fossiliferous limestones. In certain parts of the section the frequency of thin limestone "shells" is very noticeable in drilling.

SANDSTONES

The Pennsylvanian sandstones vary greatly in thickness. The sand grains, regardless of their size, are in general well sorted and rounded, and the accessory minerals are practically all altered, with the occasional notable exception of mica and pyrite.

COALS

The Pennsylvanian coals vary in thickness from a few inches to about 8 feet, and in places they are associated with or represented by black or very dark shales. The purity, thickness, etc., of the coal vary from locality to locality. "Coal places" are very numerous all through the "younger Pennsylvanian."

FOSSILS

The only fossil found in Pennsylvanian drill cuttings that is known to have value for correlation purposes is one of the foraminifera known as *Fusulina cylindrica* var. *ventricosa,* or as *Girtyina ventricosa.* This fusulina occurs

[54]Petrographer, U. S. Geological Survey, Washington, D. C.

abundantly with *Chonetes mesolobus* and other non-specific fossils in a limestone recognized by its typical and elsewhere unduplicated association with coal, and is the best horizon marker of the Pennsylvanian. It occurs with other fusulinas in other limestones in the Pennsylvanian but neither as abundantly nor in the typical association.

CORRELATION

IMPRACTICABILITY OF CUSTOMARY PENNSYLVANIAN SUBDIVISION

Subdivision of the Pennsylvanian into Pottsville, Carbondale and McLeansboro on a lithologic basis is not feasible in this area, because the Pennsylvanian strata lack the distinguishing lithologic features commonly characteristic of them and commonly used in their subdivision into the three formations elsewhere. This situation was just beginning to be realized during the course of preliminary work on this report, but as the work advanced it became apparent that many of the subdivisions and correlations made by preceding workers were in grave error. The following paragraph records one such supposed error, typical of many others.

The original Pennsylvanian correlations of the Danville area[55] were made before the dependability of the *Girtyina ventricosa* limestone as a horizon marker had been recognized. In the new correlation presented in this report, the identification of No. 6 coal is based on stratigraphic sections that are practically continuous from Crawford County, where Dr. J. A. Udden[56] identified No. 6 coal beyond question, through its association with the *Girtyina ventricosa* limestone. Correlated on this basis the coal horizon at Danville hitherto always classified as the No. 2 horizon appears to be a little above the No. 6 horizon,—if true, a conspicuous miscorrelation. Material support of this new correlation is to be had in Dr. H. E. Culver's identification of the type *Girtyina ventricosa* limestone in outcrops along Wabash River from Covington to Silverwood in Indiana; this limestone, if projected westward from the Indiana outcrops in accord with the regional dip would lie approximately at the horizon hitherto correlated as No. 2 in the Danville area, thus confirming the idea that the coal in question lies more nearly at the true No. 6 horizon. It follows also, then, that the coals best developed in Douglas and Coles counties lie a little above the No. 6 coal horizon, and that the coals hitherto correlated as Nos. 6 and 7 in the Danville area lie at least 250 feet above the No. 6 horizon. The new correlations also explain and to a considerable extent eliminate the erratic and surprising variations in intervals between coals which appeared to exist under the old correlations.

With increase in paleontological data, it is probable that correlations far more accurate and detailed than those worked out in this report will be made. Among the several workers already engaged in assembling and studying such data, are Drs. H. E. Culver, A. C. Noé, and Reinhardt Thiessen. At this writing, Dr. Culver is making a thorough study of the occurrence of *Girtyina ventricosa* and its dependability as a horizon marker, and Drs. Noé and Thiessen are approaching the problem from a paleobotanical standpoint.[57]

55Kay, F. H., and White, K. D., Coal resources of District VII (Danville): Illinois Min. Inv. Bull. 14, 1915.

56Udden, J. A., Some deep borings in Illinois: Illinois State Geol. Survey Bull. 24, pp. 98-117, 1914.

57Note: Contributions made to the subject by these workers since the writing of this report are as follows:

Culver, H. E., Pennsylvanian correlation in northwestern Illinois: Bull. Geol. Soc. America, vol. 35, pp. 321-328, 1924.

Noé, A. C., Pennsylvanian flora of northern Illinois: Illinois State Geol. Survey Bull. 52, 1925.

It is not known as yet whether the evidence of plant life is adequate in itself for the identification of a coal, but it is thought that the plant life of any particular group of coals will be recognizably similar throughout that group. As a result of Dr. Reinhardt Thiessen's microscopic study of coals,[58] it may eventually become possible to correlate coals with complete accuracy on the basis of some distinctive plant residuum in each coal. The data available for correlation at the present time are obviously inadequate for complete, authoritative recorrelation and re-subdivision of the Pennsylvanian strata of the area. But it has been deemed wise to discard completely the subdivisions and correlations made earlier, rather than to continue their use when they are so confidently believed to be mistaken, at least in part. Thus all logs and outcrops were recorrelated expressly for this report. No attempt was made to carry such correlations into greater detail than the existing data justified, and accordingly these newer correlations could not be applied to all parts of the Pennsylvanian section in all parts of the area. In fact, it was possible to classify the strata definitely as of Pottsville, Carbondale, or McLeansboro age in but comparatively few instances.

One possible subdivision of the Pennsylvanian strata was apparent in most instances, however, namely the one marked by the major unconformity in the midst of the Pennsylvanian. And so important is this unconformity in several ways that where the terms Pottsville, Carbondale and McLeansboro could not be applied confidently, the subdivisions "older" and "younger Pennsylvanian," to represent respectively the strata below and above this unconformity, were used instead.

HORIZON MARKERS USED

The principal key horizons of the Illinois Pennsylvanian are No. 6 and No. 2 coals, which by definition lie respectively at the top and bottom of the Carbondale formation.

The basis for identifying No. 6 (Herrin) coal is the recognition of a certain persistent limestone lying closely above that coal. Among other fossils this limestone contains a fusulina, *Girtyina ventricosa,* which is especially characteristic, and for which the limestone is named. The fossil *Girtyina ventricosa* is not restricted to this limestone but is everywhere present in it; and, further, the maximum thickness of the section through which *Girtyina ventricosa* occurs is thought by Dr. H. E. Culver to be not more than 50 feet. Fusulinas occur elsewhere in the Pennsylvanian section, but the association of a limestone abundant in *Girtyina ventricosa* with a typical sequence of coals and shales is not duplicated at any other horizon. Thus, No. 6 coal is believed to constitute the most dependable key horizon in the Illinois Pennsylvanian.

Outcrops of the *Girtyina ventricosa* limestone and its associated strata in Indiana are described on page 73.

The basis for the correlation of No. 2 (La Salle) coal is found in its position relative to No. 6 coal, its lithologic character as well as that of associated beds, and the plant life of the horizon. It is important to note that correct correlation of No. 2 coal depends on correct recognition of No. 6 coal.

SOURCES OF DATA AND METHODS OF CORRELATION

The sources of data were of two general sorts, sub-surface records and outcrops. The sub-surface records were diamond-drill cores and logs, churn-

[58] Thiessen, Reinhardt, Structure in Paleozoic bituminous coals: U. S. Bur. Mines Bull. 171, 1920.

drill cuttings, and logs of oil wells, dry holes, water wells, and coal tests. The sub-surface data were of much greater importance than the outcrops. With the important exception of the Wabash River outcrops in Indiana, comparatively little use was made of data from outcrops.

Most of the well logs were not based on study of samples and were detailed only at the horizon of the oil sands; but for each locality some samples were generally available, against which the logs could be checked.

Wherever oil sands interbedded or associated with coals were practically continuous, a more or less continuous correlation of the coals was possible. But where the coals were not interbedded with the oil sand, most oil-well logs did not record the coals, or, if coal was noted, it was usually as a single bed even though several coals were present. A combination of conditions is responsible for the inaccuracy with which coal is recorded in oil records. When most of the field was developed neither the operator nor the driller had any interest in the coal or in the application of simple geology. And even though the operator or the driller is somewhat interested, the pressure under which the driller works and the speed of drilling through Pennsylvanian strata render the accurate recording of coals very difficult. Under such conditions it is especially difficult to judge correctly the thickness, purity, etc., of a coal seam. In addition, black slates or shales are easily confused with coal. To complicate the matter further, cores, samples, and detailed logs show that the Pennsylvanian has many horizons of black shale and slate, coal streaks, and clean thicker coals, and the extent to which coal is developed at each of these different horizons varies markedly from place to place even within short distances.

The methods of correlation were decided upon with the above facts as to the dependability of well logs in mind. Instead of trying to choose and use type logs, it was decided to make up composite logs for every locality where logs were sufficiently numerous. The coals recorded in some of the individual logs were noted in the composite logs as "coal places." The thorough study of sand records made in connection with other parts of this report was especially helpful in the construction and comparison of the composite logs.

In the sections which follow, the coals were not drawn to scale as their thicknesses were exaggerated for the sake of emphasis of their presence and position.[59]

In projecting intervals between coals laterally, the possibility of variation of interval due to lateral variation in the sort of rock occupying the interval was not overlooked; but the conclusion was reached that in the part of the section concerned probably each locality received apparently the same types of sediment in practically the same proportions as did the adjoining localities. Further, exactness of correlation is not imperative within about 25 feet.

CORRELATION SECTIONS AND COMPOSITE LOGS

The correlations of the Pennsylvanian strata made for this report are shown graphically in Plates X and XI, which are north-south and east-west sections respectively. Some explanatory comments are given in the following paragraphs.

COMPOSITE LOG OF CENTRAL CRAWFORD COUNTY

The composite log for central Crawford County (No. 1, Pl. X) was based on descriptions of samples from wells in Crawford County made by J. A. Ud-

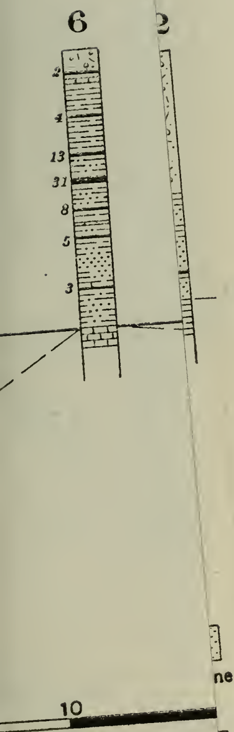
[59]It should be noted that very few of the coals referred to here have sufficient thickness to be considered workable seams at this time. Further, only core-drill data should be used in considering these coals from a commercial standpoint.

.l, the No. 6
es, and clean
ıg, but sandy

ıe horizon of
ıorizons both
l represented
No. 2 coals
l beds is the
o streaks of
correlations
ɔunty are of

ted from a
ands. The
: the lower
ower coals

composites,
he discon-
e different
two areas.
depths at
It shows
le instead
ɔortant to
No. 6 coal
ıelow the



R POOLS

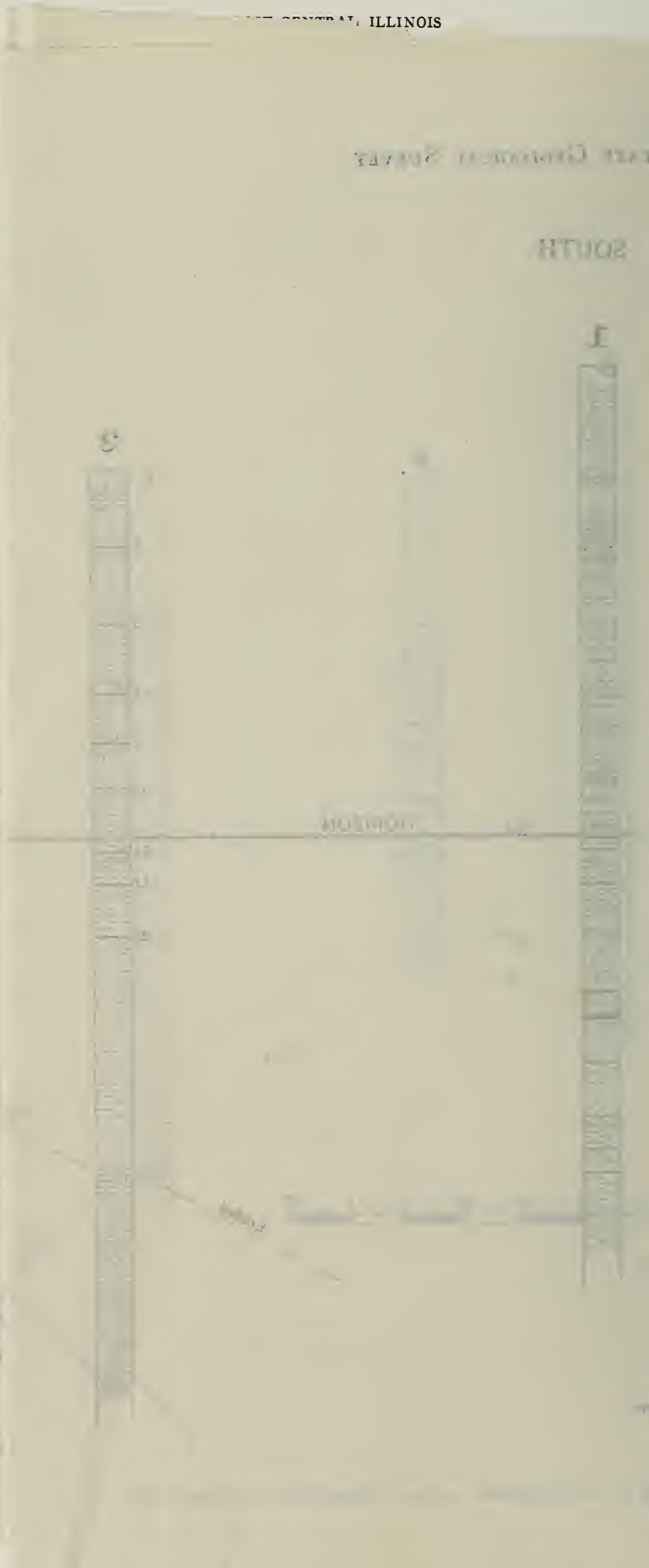
ins, and
detailed
Except
ıcerning
largely
he com-
Pennsyl-
ıe com-
Pennsyl-
ıite log
feet of
ɔart of
Penn-
ınd in
Chester

ɔm
l at

ıll. 24,

ɔn from Crawford nina

drill cuttings, a
sub-surface data
the important e
little use was m
Most of th
only at the hor
generally avail
Wherever
continuous, a m
where the coal
not record the
though several
for the inaccu
the field was
the coal or in
or the driller i
and the speed
recording of c
to judge corre
slates or shale
cores, samples
of black shal
to which coal
from place to
The me
the dependab
type logs, it
were sufficier
were noted i
records made
ful in the co
In the
thickness
position.[59]
In proj
of interval
was not ov
section con
of sediment
Further, ex



The c
graphically
respectivel

The c
on descrip

[59]It sh
ness to be
be used in

den.[60] The *Girtyina ventricosa* limestone with its underlying coal, the No. 6 bed, was taken as the datum horizon. Limestones, coals, black shales, and clean sandstones of the individual logs were included in the composite log, but sandy shales and shales were omitted.

The log shows a very marked scarcity of limestones below the horizon of the No. 6 coal, and the presence of coal and black shale at many horizons both above and below this coal. Though the No. 2 coal horizon is well represented by streaks of coal, the exact measure of the interval from No. 6 to No. 2 coals is indefinite because there is no way of deciding which of the several beds is the true No. 2 coal. It is also apparent from the log that at least two streaks of coal are commonly found at the general horizon of No. 6 coal. The correlations made show further that the producing sands of central Crawford County are of lower Carbondale age.

COMPOSITE LOG OF THE BELLAIR POOL

The Bellair pool composite log (No. 2, Pl. X) was constructed from a study of the available detailed logs and of the structure of the oil sands. The number of logs reporting each coal is shown on the composite; that the lower coals are associated with the pay sands explains the fact that the lower coals are recorded in more logs than are the upper coals.

In correlating the Bellair and the central Crawford County composites, the chief considerations were the positions of the limestone strata, the discontinuity of some of the prominent limestones, the intervals between the different coal horizons and the general structural features and relations of the two areas.

The Bellair pool composite shows the presence of Chester beds at depths at which Pennsylvanian strata are present in central Crawford County. It shows also a development of prominent sand bodies in the upper Carbondale instead of in the lower Carbondale as in central Crawford County. It is important to note that Pennsylvanian beds which occur less than 125 feet below the No. 6 coal horizon at Bellair probably correspond to beds more than 335 feet below the No. 6 coal horizon in central Crawford County.

COMPOSITE LOGS OF THE JOHNSON, CASEY AND MARTINSVILLE, SIGGINS, AND PARKER POOLS

Composite logs for the Johnson, Casey and Martinsville, Siggins, and Parker pools (Nos. 3, 4, 5 and 6, Pl. X), were constructed after a detailed study of the oil sands, using the coals and other information available. Except in the Parker and in the Casey and Martinsville pools, information concerning Pennsylvanian limestones was rarely recorded, so that correlations were largely based on the coal intervals and oil sands. Some of the coals shown in the composites could not be present in some individual holes because the pre-Pennsylvanian rock surface is locally too high; and basal beds not shown on the composite may be found in other individual holes where the pre-Pennsylvanian surface is especially low. For instance, the Casey pool composite log (No. 4, Pl. X) shows about 35 feet of Chester beds and about 90 feet of Pennsylvanian below the No. 6 coal horizon; whereas in the southern part of Casey Township, on the one extreme, notably greater thicknesses of both Pennsylvanian and Chester exist in and adjacent to the productive zone; and in north Casey Township, on the other extreme, less Pennsylvanian and no Chester are found in the producing zone.

[60] Udden, J. A., Some deep borings in Illinois: Illinois State Geol. Survey Bull. 24, pp. 96-109, 1914.

It will be seen from these four composites that the prominent sand horizons of the Johnson, Casey, Martinsville, Siggins, and Parker pools occur well up in the McLeansboro formation.

LOGS NORTH OF PARKER TOWNSHIP

Correlation north of Parker Township, Clark County (see Pls. X and XI) is based on logs compiled from drill cuttings and diamond-drill cores, and on drillers' records. North of Parker Township the logs available were commonly more detailed than were those of Crawford County and for this reason it was possible to use typical logs, rather than composites, for the northern part of the area.

The most prominent coal in the vicinity of Oakland, Coles County (see Nos. 9, 10, and 11, Pl. X), lies approximately 120 feet above the place of No. 6 coal of Crawford County. Where the Pennsylvanian is thinnest in Douglas and Coles counties the basal members are apparently all McLeansboro, no remnants of older Pennsylvanian being found (see, for example, Nos. 12, 13, 14, and 15, Pl. X). Where the lowermost McLeansboro beds are sandstones they take the place of coal horizons that would otherwise be expected.

LOGS FROM DOUGLAS COUNTY TO THE DANVILLE COAL AREA

In correlating from Douglas County to the Danville coal area (see Pl. XI), all the available logs in the intervening territory and type logs of the Danville area were used. Further information was obtained from some diamond-drill cores taken by Messrs. Swallow, Bookwalter, Phillips, et al, of Danville, still farther east, in the vicinity of Perrysville, Indiana.

The marked development of limestones in the part of the section hitherto correlated as Carbondale at Danville is very noticeable. (See Nos. 12 to 16, inclusive, Pl. XI.) Such prominence of limestones is very unusual for the Carbondale but typical of the McLeansboro, and thus accords with the new correlation here made.

Study of the available drill cuttings and diamond-drill cores has served to indicate the position of the pre-Pennsylvanian erosional surface, that is, the eroded top of the Lower Mississippian, and has shown also that progressively lower Pennsylvanian beds come in on this old pre-Pennsylvanian surface eastward toward Indiana as indicated by eastward thickening of the Pennsylvanian section. For instance, at Newman (No. 6, Pl. XI), the place of No. 6 coal is at a level that would be about 50 feet below the pre-Pennsylvanian surface; at Hildreth (No. 9, Pl. XI) it appears to be about 60 feet above the pre-Pennsylvanian surface; at Glenburn (detailed logs Nos. 3 and 15)[61] it is considered to be about 93 feet above; in the Danville coal area (No. 14, Pl. XI) it is found about 150 feet above; and at outcrops along Wabash River from Covington to Silverwood (represented by No. 18, Pl. XI) it is shown by cores and logs (Nos. 17, 19, and 20, Pl. XI) to be approximately 200 to 250 feet above. The eastward increase in thickness of the Pennsylvanian below No. 6 coal is well illustrated on Plate XI. An eastward increase in the thickness of the "younger Pennsylvanian" between No. 6 coal and the inter-Pennsylvanian unconformity (that is, the unconformity which separates the "older" from the "younger Pennsylvanian") is also indicated by study of the logs and cores. Sim-

[61] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

ilar eastward thickening and westward overlapping is found in other parts of the area.

The Pennsylvanian in the Perrysville, Indiana, cores (see Nos. 17, 19, and 20, Pl. XI) is Carbondale with perhaps a little Pottsville at the base. In the cores of the two holes that passed through the Pennsylvanian into the Mississippian many pieces of "gun-metal" shale, characteristic of the "older Pennsylvanian," were found embedded in a "younger Pennsylvanian" conglomeratic sandstone. The position of the unconformity within the Pennsylvanian in this vicinity is thus definitely marked.

OUTCROP CORRELATIONS IN AND NEAR THE DANVILLE AREA

Dr. H. E. Culver's brief examination of the Indiana outcrops of the *Girtyina ventricosa* limestone and its associated strata, described on page 73, assisted materially in confirming the interpretations made from well logs. Outcrops east of Wabash River in two localities in particular seemed to show unconformable relations between the "younger Pennsylvanian" formations and the "older Pennsylvanian" or gun-metal shale horizon. One is in a creek a mile north of "The Glens" and three miles south of Covington, Indiana, and another two or three miles southeast of Veedersburg, Indiana, on the main creek near the Coats stock farm.

INTER-PENNSYLVANIAN STRATIGRAPHIC AND STRUCTURAL RELATIONS

As shown by the above correlations, northward No. 6 coal lies progressively closer and closer to the eroded pre-Pennsylvanian surface, and within a large portion of the northern part of the area the pre-Pennsylvanian surface was too high to allow any Pennsylvanian deposition during No. 6 coal time.

But in addition to the overlap of the Pennsylvanian on pre-Pennsylvanian formations, "younger Pennsylvanian" strata apparently overlap basal or "older Pennsylvanian," as indicated by the following conditions:

The "older Pennsylvanian" extends as far north as Casey Township on the Bellair-Champaign uplift, and much farther north in the adjacent synclines, remnants appearing in drill holes in sub-areas E and F, and near Perrysville, Indiana, as well as in outcrop in Indiana in the vicinity of Wabash River; but the "younger Pennsylvanian" strata in general extend beyond the limits of the "older Pennsylvanian" as shown in Plate XXIV. Further, in central Crawford County No. 6 coal is probably about 335 feet above the "older Pennsylvanian"; at Bellair, probably about 125 feet above; in Casey Township, Clark County, locally only 50 to 75 feet above; and in Parker Township, no "older Pennsylvanian" remains on the structural highs. Such data as these strongly suggest,—though they do not completely prove,—that the contact of the "gun-metal" shales with the overlying irregular sandstone mark local, if not regional, unconformity between the "younger" and the "older Pennsylvanian." The overlapping "younger Pennsylvanian" beds vary greatly in age, probably from upper Pottsville to upper Carbondale or possibly McLeansboro. The intervals of the "younger Pennsylvanian," both where it overlaps "older Pennsylvanian" and where it lies directly on pre-Pennsylvanian beds, are rather uniform, indicating that erosional unconformities within the "younger Pennsylvanian" are either absent or of importance only locally.

The "older Pennsylvanian" is more nearly conformable with the pre-Pennsylvanian surface on which it rests than is the "younger Pennsylvanian." The latter exhibits marked discordance with the pre-Pennsylvanian surface.

PENNSYLVANIAN STRATIGRAPHIC AND STRUCTURAL RELATIONS

The lowermost Pennsylvanian beds vary in age from place to place in this area from Pottsville to McLeansboro or from "older" to "younger Pennsylvanian," and unconformably overlie formations ranging from upper Chester in the southern part of the area to basal Lower Mississippian in the northeastern, and possibly to Devonian in the northwestern part of the area. Where the presence of the "older Pennsylvanian" has been recognized, these strata overlie beds varying in age from upper Chester to Warsaw.

Details of Pennsylvanian structural relations will be brought out in the descriptions of the various pools, Chapter VI. Table 10 gives in a very general way the variations in elevation of the base of the system. Table 13 indicates indirectly and approximately the tendency towards lesser structural relief in the Pennsylvanian, particularly the "younger Pennsylvanian," than in the associated deeper horizons.

The geologic history of the area, particularly the features described in the section entitled "Resumé of foldings," is especially important to an understanding of the Pennsylvanian structural relations. It is important to note that generally structural highs were developed in Pennsylvanian strata approximately directly above the structural highs,—which were commonly also the erosional highs,—of post-Chester pre-Pennsylvanian time.

ASSOCIATION OF SAND HORIZONS WITH UNCONFORMITIES

In general, the amount of sand in the "younger Pennsylvanian" is distinctly greater in the beds close either to the eroded upper surface of the "older Pennsylvanian" or to the pre-Pennsylvanian erosion surface, than in beds not so close. For example, two cores taken near Oakland (detailed logs Nos. 67 and 71)[62] show a conspicuous development of basal Pennsylvanian sandstone resting on the eroded Lower Mississippian top.

In general wherever Pennsylvanian strata, whatever their formation, lie on or closely above an erosion surface, they tend to be conspicuously sandy. Thus much sand is found locally in this area in formations which elsewhere lie higher above an erosion surface or farther from their ancient shorelines and which therefore are relatively less sandy.

Such conditions as the above account in great part for the failure of the Pennsylvanian formations of this area to exhibit the general characteristics commonly ascribed to them in Illinois geologic literature as well as for the difficulty of differentiating and correlating the Pennsylvanian in this area. The logs, samples, and cores which support the above conclusions are so numerous and so widely distributed over the area that there would seem to be little doubt as to their correctness.

STRUCTURE

The major structural features of the area have already been outlined in Chapter II, and the structural relations between the different systems and series have been stated briefly as part of the preceding descriptions of the strata of the area. The final section of this chapter, devoted to statement of the geologic history, will include a record of the various earth movements which from time to time have affected the area and which have produced the existing structures.

[62]A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

Plates XX, XXII, and XXVI to XXXI, inclusive, are more or less detailed structure maps of those parts of the area for which sufficient structural data were available. These maps will be discussed in more detail in Chapter VI, and referred to again in the recommendations for future prospecting, Chapter VII.

Here it will suffice to point out that the oil pools are to a notable extent coextensive with the known domes, noses, and flats on the Bellair-Champaign uplift; for example, the main Siggins, Parker, Martinsville, South Johnson, Vevay Park, York, and Casey pools are either wholly or in part associated with well-defined domes, and the Bellair, North Casey, Casey, and North Johnson pools either wholly or in part with lesser domes, warpings, or flattenings.

GEOLOGIC HISTORY

Foreword

The geologic history of an area is essentially a chronologic record of the advent and withdrawal of successive seas that overspread it and of the accompanying erosion and movements of the earth's crust.

The geologic history of the area of this report, presented herewith, begins with Kimmswick time. The history of earlier Ordovician and pre-Ordovician time is not included because the drill has penetrated strata older than the Kimmswick within the area in but a very few places, and none older than Ordovician, so that the data for pre-Kimmswick history are not available.

Ordovician Period

KIMMSWICK TIME

During Kimmswick time, a sea covered the area of this report. Its shorelines are believed to have been far away because limy sediments such as go to make up a thick extensive limestone like the Kimmswick are known to accumulate comparatively far from shore in broad seas. Certainly the sea was continuous south and west across Illinois into Missouri, for the Kimmswick extends without interruption in that direction. Whether or not the sea extended very far north of the area is a problem the solution of which depends upon whether or not the Kimmswick of this area continues northward and merges with the limestone correlated as Galena-Platteville in northern Illinois. The evidence at present available neither proves nor disproves the existence of a Galena-Platteville sea separate from the Kimmswick sea.

If the sea withdrew from the area at the close of Kimmswick time, certainly it must have been only temporarily and the land must not have been raised high above sea level, for the Kimmswick gives no evidence of having been eroded at the close of Kimmswick time within this area. Farther north, however, the "Trenton" was eroded to some extent, the amount of truncation increasing northward, denoting a longer period of withdrawal and greater elevation of the land above sea level in that direction.

MAQUOKETA TIME

At the close of Kimmswick time, sea conditions changed in the area—either without or with only temporary withdrawal of the waters—with the result that the Maquoketa sediments were predominantly muds, whereas those of

Kimmswick time had been lime oozes. A decrease in the total thickness of the Maquoketa and an increase in the thickness of its middle limestone member northward in the area, would suggest that the southern part of the area lay closer to the shoreline of the Maquoketa sea than the northern part. This is in agreement with the occurrence of a sandstone, the Thebes, at the Maquoketa horizon south of the area. The changing character of the Maquoketa sediments, both laterally and vertically, is in marked contrast with the uniformity of the Kimmswick limestone. The conditions seem to indicate that the shoreline was much closer to the area during Maquoketa than during Kimmswick time, and that it perhaps shifted from time to time.

The northward thinning of the Maquoketa strata suggests the probability of temporary withdrawal of the sea and slight erosion after the close of Maquoketa time. It is believed that the erosion must have been only slight, for no evidence of marked erosion is found, and the top surface of the Maquoketa is extremely uniform. Perhaps the greater proportion of limestone in the northern part of the area may be sufficient to account for the northward decrease in thickness of the Maquoketa.

The fact that the base of the Maquoketa formation varies in elevation from about 500 feet to about 4,800 feet below sea level, whereas the maximum variation in thickness is only about 75 feet, indicates that the earth movements that produced the present variations in elevation could not possibly have taken place until long after Ordovician time.

Silurian Period

Conditions of deposition in the sea that covered the area in early Silurian time were very different from those in the Maquoketa sea, as proved by the present abrupt change from the shale of the Maquoketa to the basal limestone of the Silurian. All through Silurian time the waters covering the area were apparently part of a broad sea whose shorelines were far distant from the area, for little clastic sediment was included with the lime oozes deposited on the sea bottom. The lesser amount of coloring matter and shaliness northeastward and the increase in shale northwestward suggest that the source of sediment and probably therefore the nearest shoreline was to the south and possibly west as in Maquoketa time.

The silicification and dolomitization of the limestone in the upper part of the Silurian suggest a withdrawal of the sea and subjection of this upper part to land conditions for a long period of time; but erosion during this period must have been very slight or at least extremely uniform, for the present thickness of the Silurian strata is very regular.

Devonian Period.

In the sea that overspread the area during Devonian time, sediments of different character were deposited in the northern and southern parts of the area, —lime oozes in Crawford County, sandy limes and sands in Clark County and northward. This condition suggests that the source of the clastic sediments laid down in the Devonian sea was north of the area, a suggestion which is strengthened by the fact that during Devonian time truncated older beds containing large quantities of sand lay north and east of the area.

At the close of Devonian deposition, sea waters probably withdrew from the area and the upper members were eroded, this erosion producing a great

part, if not all, of the present maximum variation of 450 feet in the thickness of the combined Silurian-Devonian. The amount of erosion was greatest in the northern part of the area where locally all Devonian strata were removed so that now the Sweetland Creek directly caps Silurian beds. In view of this condition, it would seem that the earth movements of post-Devonian pre-Sweetland Creek time resulted in earlier submergence of the southern than the northern part of the area.

From the fact that the (assumed) base of the Devonian system varies in elevation from 350 feet above to 3,900 feet below sea level, whereas its maximum variation in thickness is less than 450 feet, it is apparent that the erosion productive of the variation in thickness long antedated the elevation and folding of the Bellair-Champaign uplift.

Mississippian Period

LOWER MISSISSIPPIAN SUB-PERIOD

SWEETLAND CREEK TIME

In the Sweetland Creek sea which advanced over the eroded Devonian and Silurian formations in Lower Mississippian time, muddy sediments of very uniform character and thickness were deposited over the whole area.

The slight northward thinning of the Sweetland Creek shale bears little if any relation to present structure, but is due instead chiefly if not wholly to the slope of the erosional surface on which it rests. Apparently the uplifts and foldings which brought the formation to its present attitude, its base lying at elevations varying from 500 feet above to 3,400 feet below sea level, all post-dated Sweetland Creek time.

UPPER KINDERHOOK TO STE. GENEVIEVE TIME

Changed sea conditions after Sweetland Creek time resulted in lateral variation in the sediments deposited above the Sweetland Creek. For example, in Crawford County the Upper Kinderhook and the Osage (that is, the Burlington, Keokuk and Warsaw) are entirely limestone whereas northward in Clark County the Upper Kinderhook is essentially all shale, and considerable of the Burlington is sandy shale or sandstone; in Coles, Douglas, and Edgar counties, the Upper Kinderhook, Burlington, and Keokuk are practically all shale, sandy shale, and sand, though a few thin limestones occur with decreasing regularity in the upper part of the Burlington and in the Keokuk; and northwestward and westward, these limestones seem more persistent and the Upper Kinderhook and Burlington shales and sandstones cleaner. Still broader regional variation in the character of the Upper Kinderhook sediments is cited on page 111. The changing character of the strata seems to indicate that the Upper Kinderhook sea conditions were transitional between those of Sweetland Creek time on the one extreme and Burlington on the other; and that the source of supply was from the northeast, and at a comparatively short distance from this area. Microscopic examination of Lower Mississippian sand suggests that it is in part detritus from some crystalline rock, indicating that possibly the great thickness of sandy Mississippian had its main source in igneous rocks, if not directly at least after relatively slight reworking.

The fact that the Spergen formation, overlying the Osage group, comprises rather regular limestone beds over the whole area, suggests a marked change, perhaps a broadening of the Mississippian sea near the close of Osage time,

It is probable that this same sea persisted through St. Louis and Ste. Genevieve times, for no evidence exists to indicate general withdrawal until the close of Ste. Genevieve time.

That the area was elevated well above the sea at the close of Lower Mississippian time, and that it was subject to erosion for a considerable time, is shown by the fact that Chester strata overlie Lower Mississippian strata ranging in age from Spergen to Ste. Genevieve.

It is only where Chester strata cap Lower Mississippian that the amount of erosion of Lower Mississippian prior to Chester time can be judged, for elsewhere the erosion of the Lower Mississippian strata is due largely to post-Chester and Pennsylvanian erosion. Thus, where Chester is known to cap Lower Mississippian, the maximum known variation in thickness of the Lower Mississippian is only 500 feet but where the Chester cap is missing the Lower Mississippian has a maximum variation of about 1,100 feet. The relative evenness of the erosion surface produced while the area was land following the close of Lower Mississippian time, suggests a simple regional uplift without marked folding, similar to the movements that affected the older formations. In further support of the idea that no marked folding of the area preceded Chester time, are the following conditions: (1) where Chester caps Lower Mississippian, the Lower Mississippian erosional highs are not related to present structure, whereas elsewhere such highs coincide approximately with present structures; and (2) the variation in thickness of the Lower Mississippian is negligible compared with variations in elevation of its base,—ranging from approximately 500 feet above to 3,400 feet below sea level.

UPPER MISSISSIPPIAN (CHESTER) SUB-PERIOD

It is very possible that the period of emergence and erosion which closed Lower Mississippian time in this area may have persisted to some extent into Chester time, and in part at least, may have accompanied the sea conditions which gave rise to the deposition of Chester beds. Certainly the Chester of this area includes a greater proportion of clastic sediment than does the typical Chester of southern Illinois. The alternation of beds of thin limestones, sands, and shales, and their lateral variation indicate that changes in the Chester seas were many and rapid and that often large areas of water, probably shallow, were affected by numerous local changes in depth, currents, wave action, and character of the incoming sediments. The local and regional relief of the eroded Lower Mississippian probably controlled the type of Chester sediments locally. The chief source of the Chester sediments in general lay to the north, and Chester beds were deposited overlapping northward the somewhat eroded surface of the Lower Mississippian.

Land conditions again prevailed in the area at the close of Chester time. The movements that produced the withdrawal of the Chester sea are believed to have been relatively simple, but the fact that the Chester thickens consistently southward and also locally off present structures suggests that possibly the first of the series of earth movements resulting in the present Bellair-Champaign uplift and associated structures, may have taken place during Chester time. Withdrawal of the sea from the area closed Chester time. The marked erosion which followed removed great thicknesses of strata, so that the first of the Pennsylvanian deposits probably overlapped truncated formations ranging in age from Upper Mississippian to Devonian, and, north of the area, successively older beds to Ordovician.

Pennsylvanian Period

HISTORICAL SUMMARY

Details of Pennsylvanian history are not well understood, but its major events are clear.

As Pennsylvanian waters spread over the area, probably encroaching from the south, considerable thicknesses of sediments were deposited over the eroded pre-Pennsylvanian surface. Somewhere near the middle of Pennsylvanian time this early Pennsylvanian sea withdrew temporarily from the area, with marked emergence, erosion and considerable warping of the strata. It was then that the first of the marked foldings that produced the Bellair-Champaign uplift as it is known now, took place. When the sea began its return to the area, again encroaching from the south, it advanced over an irregular eroded surface, the conspicuous feature of which was the upstanding wedge-shaped area of the Bellair-Champaign uplift. In the early stages of the advance, the relatively low areas to the east and west of the uplift were submerged first leaving the uplift as a point of land. Later the point too was gradually submerged, its southern part first. In the advancing sea, "younger Pennsylvanian" sediments were deposited overlapping truncated "older Pennsylvanian" beds and, where such beds were missing, pre-Pennsylvanian beds. That the "younger Pennsylvanian" strata extend far beyond the limits of the "older" as mapped on Plate XXIV, does not in any way prove the later sea to have been more extensive than the earlier. As a matter of fact the earlier sea may have been much more extensive, but the erosion that followed its withdrawal destroyed all evidence as to the original extent of the "older Pennsylvanian" strata and the earlier Pennsylvanian sea. Withdrawal of the later Pennsylvanian sea, accompanied by another marked upwarping of the Bellair-Champaign uplift accompanied by erosion, closed Pennsylvanian time.

With the above outline of major events in the Pennsylvanian period in mind, the known and suggested subordinate events to be described below will be more readily understandable.

SOURCES OF PENNSYLVANIAN SANDS

The sources of Pennsylvanian sands were probably many; but of them all three were probably most important:

1. A 600-foot thickness of basal Mississippian sandy shale and shaly sandstone is completely truncated near Tuscola; a 1,200-foot thickness of the Mississippian is found in Union Township, Cumberland County, and probably a greater thickness southwest of Tuscola. From the vicinity of Tuscola the truncated surface of the lower sandy phase of the Mississippian extends in a relatively wide belt eastward into Indiana; the structural irregularities vary the trend and width of this truncated belt, but its maximum width is about 60 miles or more. These sandy Lower Mississippian formations, as described earlier in the chapter, contain large quantities of very fine to fine- and medium-grained sand, mostly angular to sub-angular, and the finer sands more angular than the coarser; in general the sediments were rather poorly sorted, except at and near the base. Truncation of these Mississippian strata in Pennsylvanian time doubtless brought a large amount of sand into the Pennsylvanian seas where it was first reworked and then deposited as Pennsylvanian sand. In the process, the iron and other mineral contents were weathered, the sediments as a whole sorted, and the sand grains rounded.

2. The sandy strata of the Devonian (or upper Silurian) have been truncated by erosion in the northern half of Vermilion County and vicinity, and completely removed at T. 23 N., both in Vermilion County and in the adjoining part of Indiana. Part of this erosion undoubtedly occurred before Pennsylvanian time, as indicated by the presence of Lower Mississippian strata above the Devonian-Silurian in some holes (see detailed logs Nos. 3, 4, 5, 26, and 28).[63] But part of it occurred during Pennsylvanian time, the sandy Devonian-Silurian strata thus contributing some sand directly to the Pennsylvanian seas.

3. Erosion in Pennsylvanian times also truncated Devonian, Silurian, and Ordovician sandy strata within short distances of the area. All of these formations probably supplied considerable amounts of sand. As the Pennsylvanian deposits overlapped the truncated surfaces of progressively older rocks northward along the uplift from Lawrence County, some sources of sand were thus cut off; but this was compensated by the progressive exposure of still lower beds farther north, which were not yet covered by the Pennsylvanian sea and therefore still undergoing erosion.

PENNSYLVANIAN SHORELINES

Plate XXIV shows the approximate shorelines corresponding to the different Pennsylvanian sand horizons, classified as "A" to "H," inclusive, each of which will be discussed in turn in the following paragraphs. Plate XXIII shows the stratigraphic position of each of these horizons; and on page 105, under the heading "Pennsylvanian sands as key horizons," is an explanation of the origin of this classification.

SHORELINE "F"; SANDS "F," "G" AND "H"

At the time the various sand bodies grouped as sand "F" (see Pl. XXIII) were being deposited, the Pennsylvanian shoreline had practically the position indicated on the map, Plate XXIV, as shoreline "F." The map indicates also how the outlines of the large wedge-shaped point of land bordered by shoreline "F" accorded roughly with the general outlines of the Bellair-Champaign uplift, proving that the point was due to the existence of the uplift at that time. Streams entered the basins on either side of the point, some from the high land that lay to the north, and others from the point itself. The latter probably swelled and accelerated basin currents and added clastic material. Local bodies of sand were deposited paralleling and off the shores of this point of land wherever shore and local topographic conditions (not fully determinable from present data) caused shallower water or decreased velocity of the currents; and deltas were built at the mouths of streams. Of such origin were the sands classified as "F."

Much of the clastic sediment carried into the basins by streams, was not deposited locally, however, but kept in suspension in the basin currents. While sand "G" was being deposited, the Pennsylvanian shoreline still lay practically at the position indicated for shoreline "F," and the basin currents were apparently so directed by the point of land as to meet in the vicinity or south of the Bellair pool. The resultant decrease of current velocity was in part responsible for deposition of sand in that locality as spits and other shallow-water forms. But some of the sediment-bearing current continued on southward to local islands or areas of shallow water existing wherever the pre-Pennsylvanian surface was relatively high. Thus, the area in which sand "G" was deposited must have been somewhat larger than the area mapped on plate XXIV.

---

[63] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

The conditions under which sand "H" was deposited doubtless simulated those of "F" and "G."

Shoreline "F" as mapped approximately on Plate XXIV pictures an early stage in the advance of the Pennsylvanian seas over the area and in the resulting overlap of sediments on the pre-Pennsylvanian surface. The irregularity of this shoreline was due to irregularities in the topographic relief of the area developed by uplift, folding and erosion between Chester time and "F" time. The existing data fail to show just where this shoreline crosses the La Salle anticlinal belt near the Siggins pool. But a synclinal condition between the Parker Township pool and this anticlinal belt must have existed, as well as probable synclinal embayments along the western "wall" of the uplift, forming basins into which re-entrants of the sea probably extended. Whether or not sand equivalent in age to "F," "G," or "H" was developed in any considerable thickness in these re-entrants is an open question. Doubtless, however, sands of this approximate age exist outside the areas mapped for them on Plate XXIV, but they are in general unknown and therefore cannot be mapped unless oil pools have been discovered within their areal limits. Existing data do indicate, however, that small thicknesses of sand related to shoreline "F" were deposited a few miles north of the area mapped for this sand; and that the sand is developed locally along the sides of the point of land.

SHORELINE "D"; SANDS "D" AND "E"

By the time the various sand bodies classified as sand "D" were being deposited, the shoreline of the Pennsylvanian sea had advanced to the position indicated as shoreline "D" on Plate XXIV. Shoreline "D" lay about 110 feet above shoreline "F." Locally the pre-Pennsylvanian relief had been reduced or obliterated and the area of the point of land was much less than in "F" time. But the Parker dome (T. 11 N., R. 14 W.) was still above sea level as a large prominent island at the close of time "D"; and though the map does not indicate it, the Martinsville dome was possibly a small island also. As Plate XXIV shows, a re-entrant of shoreline "D," due to the synclinal condition between the La Salle and Oakland anticlinal belts on the uplift, extended practically as far north as the latitude of Tuscola. This embayment may have been the path of rather strong local currents fed by streams from the high land at its head (that is, from around Tuscola and northward). Off the mouth of the embayment, these currents encountered the prominent Parker Township island, which stood directly in their path, and were doubtless retarded. They were probably also deflected, partly eastward and partly westward to the areas of shallow water bordering the island, and there met the currents that paralleled the outer borders of the two sub-points of land. Thus a large amount of sediment was brought into the area of very shallow water that lay east, west, and south of the Parker Township island; and the retardation of the various currents, partly due to the shallowness of the water and partly due to their meeting probably led to deposition of sands "D" and "E" rather widely in this general vicinity. The known extent of these sands is partially shown on the map, Plate XXIV. Sand "D" occurs also under the Siggins pool, but is not mapped because sand "A" is there more important. It is missing east of the Siggins and York pools, though the existence there of a synclinal basin has been shown by tests. But east of the syncline it was prominently developed in the area of the Casey Township production; and to some extent, at least, it was also developed between the Siggins and Casey pools via the North Casey pool. Deposition

was continuous from the Siggins to the York pool, but the amount of sand decreased and the sand bodies were less continuous. North, between the Parker Township island and the main shoreline "D," some sand was deposited locally at this horizon, probably as the result of small streams dropping coarse material at or near their mouths, or because locally the contour of the shore was such as to retard currents that paralleled them, or to permit waves to build sand deposits.

SHORELINE "C"; SANDS "A," "B" AND "C"

Subsequently, a marked northward advance of the Pennsylvanian sea brought the shoreline of sand-horizon "C" to the position mapped on Plate XXIV. Some islands are known and others undoubtedly existed at this time. There was a small island in Parker Township, one on the Oakland dome, and probably one near Allerton, but the mainland shoreline had retreated well beyond the shoreline "D." The eastern sub-point of land that in "D" time had marked the position of the Oakland anticlinal belt, was practically submerged by "C" time, but the Tuscola point of land, corresponding with the La Salle anticlinal belt, still jutted conspicuously south into the sea. Comparatively shallow water lay over the part of the area transgressed during the advance of the sea from shoreline "D" to shoreline "C"; its depth probably averaged less than 55 feet, which is the interval between sands "C" and "D." North of this area some Ordovician was probably still exposed and probably still continued to supply sandy sediments to the streams and to the sea. The currents coming from the basins east and west of the point of land and its associated shallows undoubtedly behaved as did the similar currents in "F" time, with the result that much sand was deposited at horizon "C" on the large shoal area, but typically in irregular small patches, due to little islands and other irregularities of the sea bottom. Similarly related currents and shallows apparently persisted on through "B" and "A" time so that sands "B" and "A" apparently originated under the same general sort of conditions as sand "C."

Though Pennsylvanian time cannot be definitely subdivided here into the three customary parts,—Pottsville, Carbondale, and McLeansboro,—it is clear that times "C," "B," and "A," were part of McLeansboro time.

The areas in which sands "A," "B," and "C" were deposited are shown in part only on Plate XXIV. The shoal area in which they were developed had a sharply defined western edge, paralleling closely the western edge of the Bellair-Champaign uplift, as indicated by the sharply defined, aligned west edges of the individual sand bodies.

The thicknesses of sand deposited far south of the point were slight, and those closer to the end of the point were progressively greater, until near Charleston, directly opposite its tip, the massive thick body was deposited which is now represented by the notably prominent McLeansboro sandstone outcrop 3 miles east of Charleston.

The southernmost of the sands at this general horizon were deposited earliest and those to the north successively later, as the sea advanced northward from "C" to "A" time. Thus is explained the fact that northward the sands of a single general horizon occur successively higher in the section.

FURTHER NOTES ON PENNSYLVANIAN SHORELINES AND SANDS

The northward rising of the pre-Pennsylvanian surface and of the important sand development in the Pennsylvanian section is brought out in part by longitudinal sections, Plates II and VIII. It should be emphasized at this point

that none of the sand horizons mapped on Plate XXIV and elsewhere, and described in the above paragraphs is a continuous development of basal sand. Instead they represent the areal extent of horizons of shale and sandy shale in which sand lenses occur. Detailed logs from the Westfield pool and other detailed logs in the Tables of Well Data bring out this point by showing that the basal Pennsylvanian beds resting directly on the pre-Pennsylvanian surface are not uncommonly shale. Only when and where the supply of clastic material carried by the currents was adequate and the position and nature of local shorelines favorable, were relatively clean bodies of sand deposited.

Although the shoreline studies have not been duplicated for Crawford and Lawrence counties, partial data regarding the position and correlation of the sands there prominently developed indicate conditions similar to those in this area. Outstanding among the similarities are the downward migration of the sand development in the section southward along the uplift; the lowering of the horizon of sand development locally in an "off-structure" direction; and the practical restriction of the important sand horizons to the anticlinal zone. Apparently in Lawrence and Crawford counties, as in Clark County and northward, it was pre-Pennsylvanian highs or ridges that controlled the location of conditions favorable for deposition of sand.

Knowledge of the successive positions of the Pennsylvanian shorelines in relation to the extent and nature of Pennsylvanian sand deposits has possible important practical application to future prospecting both in the Clark and in the Lawrence and Crawford county fields. For example such information will indicate the approximate areas and depths where there are chances for sands, and may thus be used to limit prospecting to the more promising territory.

To put the above outlined facts and ideas about Pennsylvanian shorelines to practical use is feasible chiefly because of the close relationship between those old shorelines and present structures. To be specific, in addition to controlling the areal distribution of the sands, the original post-Chester warping, doming, and folding were "lines of weakness," so to speak, to which the subsequent warping, doming, and folding approximately conformed, so that the structural highs as they exist at present serve in a general way as a guide to the configuration of the old Pennsylvanian land and sea bottom, and accordingly to the Pennsylvanian sands.

Post-Pennsylvanian Time

During the remainder of the Paleozoic era, that is during the Permian period, and during the ensuing Mesozoic and Cenozoic eras, there is no evidence to disprove and much to support the idea that the area was continually land. Until the advent of the first of the Pleistocene glaciers, it is believed that weathering and streams were actively eroding the surface. By Illinoian time the area had been reduced almost to the level of the present upper surface of the bed rock. During the spread and advance of the Illinoian ice southward across and beyond the limits of the area, the bed rock surface was smoothed and somewhat lowered; and during its melting and retreat, clay, sand, gravel, and boulders that had been included in the ice were deposited as a cover, perhaps 50 feet thick on the average, over the entire area.

Subsequently another glacier, the Early Wisconsin, advanced into the area, but did not extend south of northern Cumberland and Clark counties. For a comparatively long period of time, its southern edge lay within the belt, indicated on Plate XII as Early Wisconsin moraine, extending roughly east and

west just south of Paris and Charleston. As a result of the long stay of the ice edge, thick terminal moraines were deposited within this belt. Locally, as much as 350 feet of glacial debris accumulated in this way.

During the retreat of the Early Wisconsin ice, its edge halted locally for considerable periods of time, and the other belts indicated as Early Wisconsin moraine on Plate XII (namely, those north of the terminal morainic belt mentioned in the preceding paragraph) received thick morainic deposits. Between these morainic belts, lesser thicknesses of drift were deposited, obscuring the bed rock surface.

Since that time streams have been at work eroding the drift, but only locally has the bed rock surface been exposed.

Resume of Earth Movements

INTRODUCTION

The earth movements which affected the area prior to the close of Chester time were on the whole relatively simple regional subsidences and emergences, uncomplicated by folding. The erosion which accompanied each interval of emergence resulted in simple and commonly slight truncation of the exposed formations.

But the earth movements and erosion of late Chester and Pennsylvanian time were much more complicated, for though the movements were in part regional subsidence and emergence, they included in addition the marked folding movements that produced the Bellair-Champaign uplift and its structural irregularities.

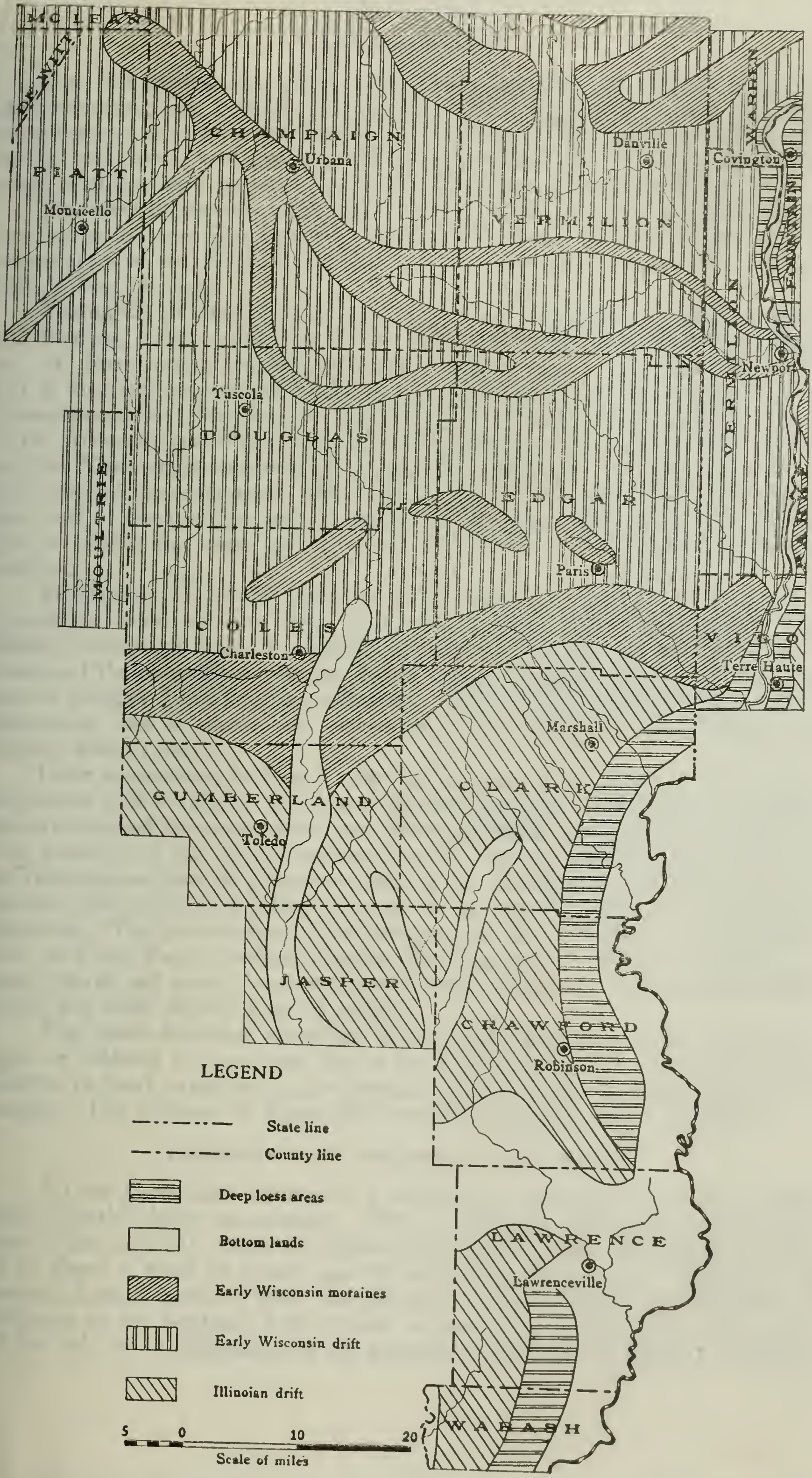
In Table 11 are listed the known earth movements of pre-Pennsylvanian time, all relatively simple regional subsidences and emergences. In Table 12 are listed the known earth movements that included folding, all of Chester and Pennsylvanian time.

Table 11.—*Earth movements of pre-Pennsylvanian time; simple regional elevation or depression*

Period or sub-period	Movement	Time
Ordovician	A_1	At close of Kimmswick deposition
	A_2	Previous to Maquoketa deposition
Silurian	B_1	Previous to Silurian deposition
	B_2	At close of Silurian deposition
Devonian	C_1	Previous to Devonian deposition
	C_2	At close of Devonian deposition
Lower Mississippian	D_1	Previous to Lower Mississippian deposition
	D_2	At close of Lower Mississippian deposition
Upper Mississippian	E_1	Previous to Upper Mississippian deposition
	E_2	At close of Upper Mississippian deposition

Table 12.—*Earth movements after late Chester time; regional elevation or depression accompanied by folding*

Sub-period	Movement	Time
Upper Mississippian	1a	At close of Upper Mississippian deposition
	1b	Previous to Pennsylvanian deposition
"Older Pennsylvanian"	2a	At the close of "older Pennsylvanian" deposition
	2b	Previous to "younger Pennsylvanian" deposition
"Younger Pennsylvanian"	3	During late McLeansboro or after Pennsylvanian time



Glacial map of Douglas, Edgar, Coles, Clark, Crawford, Lawrence, and parts of adjoining counties.

AXES OF FOLDING

The first folding, 1a, seems to have taken place in two separate areas, the one conforming in a general way with the Bellair-Champaign uplift, the other along the east side of the Marshall-Sidell syncline. The axial direction of folding in both areas was approximately north and south. Considerable thicknesses of strata were removed by erosion during and following folding 1a.

The next movement, folding 1b, occurred just previous to Pennsylvanian time, or at the very beginning of Pennsylvanian time. Its chief result was the accentuation of the Bellair-Champaign uplift. Its axial direction was probably slightly west of north.

Folding 2a produced further accentuation of the Bellair-Champaign uplift, and lowering, either relative or actual, of the eastern uplift produced by folding 1a. At least such a sequence of events readily explains the following facts: (1) in the northeastern part of the area the Pennsylvanian beds capping the pre-Pennsylvanian are older than the similar beds on the uplift; (2) successively less of the Mississippian section remains and successively older Pennsylvanian beds cap the Mississippian eastward from the Marshall-Sidell syncline; and (3) in that syncline the uppermost Mississippian beds are younger than those uppermost east of the syncline, and are capped by Pennsylvanian beds, either younger than or about the same age as those capping the Mississippian east of the syncline.

Movements 2a and 2b, which occurred during early Pennsylvanian and pre-Carbondale time, are not well understood. But further upwarping of the Bellair-Champaign uplift is indicated by a westward increase in the amount of erosion of the older Pennsylvanian strata and an eastward increase in the thickness of younger Pennsylvanian sediments. The axes of neither of these folding movements can be accurately determined, but probably their direction was slightly west of north.

Later movements, folding 3,—during "younger Pennsylvanian" or late McLeansboro time,—further raised the Bellair-Champaign uplift and in addition sharply elevated the area east of the Marshall-Sidell syncline, thus reproducing in a general way the earlier structural uplift that had existed there at the close of Mississippian time as a result of folding 1a. Folding 3 produced much more marked local relief in bedding structure in an east-west than in a north-south direction. The relationship of the structure of the "Trenton," the Mississippian, and the Pennsylvanian, suggests that the axis of this latest folding was nearly north and south, in contrast with some of the axes of preceding foldings which had been slightly west of north.

The above-described variations in the axial direction of the several foldings are believed to have been due to local variations in the rock load, related directly to local variations in the amount of rock eroded during and after each folding. The evidence of Plates XV and XVI suggests such a condition.

DISCREPANCY IN POSITION OF THE "CRESTS"

All the formations involved in a fold do not necessarily have their highest parts directly above one another. This is strikingly illustrated in the Parker pool (Plate XXVI) where the highest part of the Lower Mississippian appears to be about a third of a mile east of the highest part of the "Trenton"; the vertical distance between these two horizons is about 2,000 feet. Whether this variation in the position of the "crest" is due to inclination of the axial plane of the fold or to differences in the position of the axis of different foldings is

not known. A similar western displacement of the "Trenton" crest in the Oakland anticlinal belt is a possibility which should be borne in mind by those prospecting the "Trenton" in that territory.

QUANTITATIVE ESTIMATES OF THE MAGNITUDE OF THE EARTH MOVEMENTS AS MEASURED BY THEIR EROSIONAL EFFECTS

Table 13 is an attempt to estimate quantitatively the magnitude of the several recognized pre-Chester earth movements by determining the amount of the resultant erosion. Obviously the magnitude of any earth movement is somewhat commensurate to and can be no less than the maximum amount of the resultant erosion; and a measure of the amount of erosion is to be had in the maximum thickness variation thus produced within the area.

Part I of Table 13 states the maximum demonstrable variation in thickness produced by erosion related to each of the major movements of pre-Chester time. For example, movements A_1 and A_2 combined surely had a magnitude of not less than about 80 feet, for the Ordovician strata have an 80-foot thickness variation within the area which is definitely ascribable to the erosion resulting from these movements.

It happens that the erosion following each of the pre-Chester movements was most active in the northern part of the area and least active in the southern part. Thus as a result of erosion related to pre-uplift earth movements, the Ordovician (80), the Silurian-Devonian (400), and the Lower Mississippian (500) are altogether at least 980 feet thinner in the northern part of the area than in the southern part; and the magnitude of all these pre-uplift earth movements must have totalled at least 980 feet.

Part II of Table 13 states the maximum demonstrable variations in thickness that resulted from erosion related to each of the major earth movements of post-Lower Mississippian time. For example, movements 1a, 1b, 2a, and 2b, combined, surely had a magnitude of not less than 2,275 feet, for that is the maximum variation in thickness of Ordovician-to-"older Pennsylvanian" strata resulting from erosion related to these movements.

Like the pre-Chester earth movements, the post-Lower Mississippian earth movements were such as to induce more active erosion in the northern part of the area than in the southern; but in addition the warping and folding effects that characterized these later movements resulted in much greater erosion "on" than "off" the Bellair-Champaign uplift, and in more erosion at the structurally highest parts of the uplift than at lower parts. As a result, the greatest thicknesses of strata were eroded in the northern part of the area within the limits of the uplift, and the least in the southern part outside the boundaries of the uplift. Specifically the rock section is at least 2,775 feet thinner in the northern part of the area "on" the uplift than in the southern part "off" the uplift as a consequence of erosion induced by the post-Lower Mississippian earth movements.

The total erosional variation in thickness produced as a result of all the movements since Ordovician time is at least 3,755 feet.

RELATIONSHIP OF PENNSYLVANIAN STRUCTURE TO THAT OF OLDER STRATA

Over the central portions of anticlines and of basins, the Pennsylvanian bedding locally conforms with Mississippian and older bedding, but elsewhere the Mississippian bedding is steeper (for example, see Pls. III, VI, and XIII) and in extreme instances the change in elevation of the Mississippian bedding has been observed to be nine times as great as that of the Pennsylvanian.

Table 13.—*Maximum erosional variations in thickness resulting from the various earth movements that have affected the area; (indicative of the magnitude of the earth movements)*

Part I—Earth movements consisting of simple regional emergence and tilting

Movement	Age of strata eroded	Maximum erosional variation in thickness	
		Minimum determined	Estimated
		Feet	*Feet*
A_1, A_2*a*	Ordovician	80	100
B_1, B_2, C_1, C_2*b*	Silurian and Devonian	400	500
D_1, D_2*c*	Lower Mississippian	500	500
Total		980	1100

Part II—Earth movements including folding in addition to simple regional tilting

1a, 1b, 2a, 2b	Ordovician to "older Pennsylvanian" inclusive	2275	2600
3	"Younger Pennsylvanian"*d*	500	700
Total		2775	3300
Grand total		3755	4400

*a*Possibly also B1.
*b*Possibly also D1.
*c*Possibly also E1.
*d*Strata of Ordovician to "older Pennsylvanian" age inclusive were also eroded at this time, but the amount is not tabulated.

If the relative amount of erosion indicated accurately the relative magnitude of folding, then the figures given in Table 13 could be used to determine the relative steepness of Mississippian bedding as compared with Pennsylvanian. Thus, as the amounts of erosion of the Mississippian and Pennsylvanian were respectively at least 2,275 and 500 feet (or possibly as much as 3,300 and 700 feet), it might be expected that the relative steepness of the Mississippian and Pennsylvanian bedding would have a corresponding ratio of about 6:1 (or possibly 5:1). But actually the ratio is at least 9:1 at its maximum. (See page 128.)

From the above paragraphs it is clear that an understanding of the relationship of the structure of Pennsylvanian strata to that of Mississippian and older strata is important to consideration of deeper drilling, for there is a tendency towards greater amount of closure in the Mississippian and lower strata than in the Pennsylvanian. It is also clear from this situation that key horizons for structural investigations to determine places deserving deeper drilling should be chosen below the Pennsylvanian wherever practicable.

CHAPTER IV—USE OF LOGS, CUTTINGS, AND CORES

INTRODUCTION

Driller's logs, samples of drill cuttings, and diamond-drill or other cores of holes in or near the area, whether or not they are drilled primarily for oil and gas, can play an important part in guiding prospecting and development. As sources of data for (1) correlation, (2) knowledge of sand conditions, and (3) structure determination, they serve very important purposes. The use of logs, cuttings, and cores in each of these three ways in turn will be discussed in this chapter.

(1) USE OF SUBSURFACE DATA FOR CORRELATION PURPOSES

General Statement

On account of the marked dissimilarity of the rock section from place to place within the area, it is often difficult to correlate logs even though they have been carefully made and cuttings and cores are available. To assist others in correlation, the descriptions of the different geologic systems given in Chapter III were stated to a large extent in terms of characteristics recognizable in drill cuttings, and thus systematic description of the drill cuttings need not be repeated here. Instead, the aim of these paragraphs on correlation is to forewarn of specific difficulties that are likely to be encountered, and to point out the important contrasts between different formations and systems. Special emphasis will be given the outstanding features that may serve when no drill cuttings or cores and only poor logs are available.

Some Specific Difficulties

The composite log of the Parker pool (Plate XXV) is almost a complete typical geologic section for the entire area, to and including the "Trenton." But the formations represented in that log are not all present in all parts of the area, and unless the formations that may be expected in the various parts of the area are known in advance, anyone but an expert stratigrapher familiar with the section is confronted by almost unsurmountable correlation difficulties. Table 4 in Chapter II and Tables 6 to 10, inclusive, in Chapter III show in a general way which systems and formations are present in each sub-area, together with their approximate thicknesses and elevations. Consultation of these tables is an important first step when logs are to be correlated.

Several different parts of the stratigraphic column are especially likely to present difficulty and are therefore given special consideration in the following paragraphs. It will be seen that the difficulties are in most instances related closely to the late Mississippian and Pennsylvanian folding and the attendant erosion and deposition.

1. The Lower Mississippian-Pennsylvanian contact: Where the uppermost Lower Mississippian formations present are sandy shales ("siltstone"), the passage from Pennsylvanian to Lower Mississippian may be very difficult to detect. The Lower Mississippian beds are of this nature wherever the erosion related to the anticlinal folding removed the limy upper part of the Lower Mississippian section, leaving the comparatively non-calcareous lower part uppermost. And even where the limestones of the upper part of the Lower Mississippian (the "Mississippi lime" of the driller) were not entirely removed and where the Pennsylvanian is therefore in marked lithologic contrast with the Lower Mississippian, the marked variations in the thickness of the limestone, due to variations in the amount eroded from place to place, are puzzling unless understood.

Tables 8, 9, and 10 will in large measure help to overcome these difficulties.

2. The "older Pennsylvanian": The "older Pennsylvanian" remnant is not as extensive as the "younger Pennsylvanian" and especially near its edges where it is thin, its presence may be difficult to detect. In itself, the separation of the "older Pennsylvanian" from the "younger" is not of fundamental importance, but is advisable in order to avoid miscorrelation of some of the Chester beds and to assist studies of bedding conformity. The map, Plate XXIV, showing the approximate position of the "older Pennsylvanian" edge, should therefore be consulted as a preliminary step in correlations involving the Pennsylvanian.

The principal lithologic difference between the "older" and "younger Pennsylvanian" where both are present is that the former is distinctly more metamorphosed or cemented than the latter for its shales, sandy shales, and sandstones are distinctly harder. The "older Pennsylvanian" shales also have a characteristic gun-metal blue color not duplicated by shales of any other system.

The "older Pennsylvanian" strata may immediately overlie beds ranging in age from Chester to Warsaw.

3. Chester-Pennsylvanian contact: To complicate recognition of the Chester-Pennsylvanian contact, the upper Chester beds are locally very similar to the directly overlying Pennsylvanian beds; the Chester is extremely variable in thickness, the variations bearing direct relation to structure; and the beds underlying the Chester vary in age from Spergen to Ste. Genevieve.

The map, Plate XXIV, will be of assistance in that it shows the approximate edge of the Chester remnant. Logs alone ordinarily are inadequate, but study of drill cuttings or cores with the characteristics of Chester and Pennsylvanian in mind will commonly permit recognition of the contact with considerable accuracy.

4. Chester-Lower Mississippian contact: The Chester caps different formations of the underlying Lower Mississippian in different parts of the area, but nowhere does it cap the Lower Mississippian where all or even most of the limestone of the upper part of the Lower Mississippian has been eroded. In other words, nowhere are Lower Mississippian sandy shales ("siltstone") in contact with the Chester. On that account the passage from Chester to Lower Mississippian can be recognized after the drill has penetrated more than 50 feet of solid limestone. The oölites of the Ste. Genevieve are very similar to those oölites of the Chester, and where the Chester caps Ste. Genevieve, separation on the above basis is the only means available.

Regardless of the age of the first Lower Mississippian limestone it will show some effects of weathering, but where Chester caps the Lower Mississippian, the amount of truncation and consequently the amount of weathering is much less marked than where no Chester remains.

5. The Devonian and Silurian limestones: In most parts of the area the Devonian and Silurian beds underlie considerable thicknesses of Pennsylvanian and Mississippian strata, so that there is little chance of their miscorrelation if the overlying beds are correctly recognized. But locally, as in sub-area B, Devonian or Silurian formations may lie directly beneath the glacial drift or beneath a very slight thickness of Pennsylvanian. If this possibility is not recognized, Devonian or Silurian might be wrongly correlated as Pennsylvanian or Mississippian. Tables 7 to 10, inclusive, will be of assistance in correlations in such localities. In addition an understanding of the probable areal geologic relations will be useful; for example an area of Silurian or Devonian will be bordered by a belt of Sweetland Creek, followed by a belt of Upper Kinderhook and then by Pennsylvanian, either all covered by drift or partly or wholly by a slight thickness of overlapping McLeansboro beds.

Markers Commonly Logged

Certain salient and easily recognized features of the rock section that are helpful in correlation are very commonly if not almost invariably recorded by drillers in their logs. Some of them are listed below.

1. Pennsylvanian-Lower Mississippian limestone contact: Where the Chester is missing and the upper limestone phase of the Lower Mississippian section (the "Mississippi lime" of the driller) is present, the change from shale to limestone in drilling through Pennsylvanian into Lower Mississippian is so marked and the "Mississippi lime" so easily recognized by drillers that this junction will almost invariably be given in the logs. However, where the Lower Mississippian remaining is sandy shale ("siltstone"), the contact may not be recorded in the driller's logs.

2. Chester-Pennsylvanian contact: The passage from Pennsylvanian to Chester is commonly, but not always, recorded as a change from sandstone and shales to either conspicuous limestones or cavy shales. or to both.

3. Contact of chocolate shale (Mississippian) with Devonian or Silurian: Without exception, the contrast between the Sweetland Creek or "chocolate" shale (Mississippian) and the underlying Devonian or Silurian limestone is very marked and is rarely missed in any log, although the shale is sometimes wrongly termed Maquoketa, and the limestone, "Trenton."

4. Silurian-Ordovician contact: The break between the Silurian and the Maquoketa (the topmost Ordovician) is always clearly marked, for the Maquoketa is essentially darker in color and shaly, and this junction is therefore noted in many logs. The failure to record it in some logs is probably due to the fact that the basal Silurian varies in color and the passage into typical Maquoketa color is therefore not as likely to catch the driller's attention as it otherwise would be.

5. Maquoketa-Kimmswick ("Trenton") contact: The Kimmswick ("Trenton") limestone and its Maquoketa shale cap are in such sharp contrast that their contact is always noted in logs.

"Water Sand" as a Driller's Term

The significance of the term "water sand" as used in logs needs comment. Oil drillers and producers have noticed that in the Clark County field the sands closely related to the pay sands are commonly relatively fine-grained and commonly have water in them. Consequently the oil man invariably associates fine-grained sand with water, and such sands are rather indiscriminately logged as "water sand." As a matter of fact, much fine-grained sand does not carry water, and some of it is actually oil pay. Further, some coarse sands are incorrectly logged as fine when they are drilled with a wet hole. This is because the cuttings of a sand drilled with the hole full of water are ordinarily much finer than cuttings of the same sand drilled with a "dry" hole. The same body of sand may be logged as an "oil sand" in one locality and as a "water sand" in another, if in the one place it carries oil, and in the other, water.

Significance of Color of Beds

It has been brought out in this work that the colors of beds are very important, as difference in color is directly related to difference in type of coloring matter, and in turn difference in type of coloring matter denotes difference in depositional and subsequent conditions to which sediments may have been subjected. For example, the typical blue-gray coloring of Burlington-Kinderhook strata, whether shale, sandy shale (siltstone), sandstone, or limestone, is caused by the presence of glauconite of that color. The Sweetland Creek shale gets its chocolate color from the spore remains and the intensity of the color is directly proportionate to the amount of the spore remains. The coloring of the Pennsylvanian shales, and to a less degree the sandstones, is controlled by their content of organic matter and of weathered micas, feldspars, pyrite, etc., the unaltered minerals present having little or no effect on color. Although the Chester shales have not yet been studied under the microscope, it is suggested that in general the characteristic differences in color between the Chester and Pennsylvanian shales may be attributed to the fact that in most cases the former has its coloring controlled by relatively unaltered mineral material, and the latter by organic and altered mineral matter. The extremely fine dissemination of coloring matter in the Chester shales as compared with Pennsylvanian shales (regardless of what the particular color is) gives to the Chester a characteristic "sheen" and evenness of color which is in marked contrast with the "earthiness" and "spottiness" of the Pennsylvanian.

Though limestones ordinarily do not vary as conspicuously in color as do shales, they, also, have their typical colors. For example, white dolomites and limestones are very characteristic of, and always present in the Silurian. Red limestones are also present, but in varying color and amount.

From the above comments, it is clear that the typical colors or groupings of colors may be of great aid in correlation.

Other Lithologic Characters of Beds

The degree of cleavage and fissility of the different strata, the nature and extent of sorting of the constituent grains, the type of sediment, the nature of the cement in sandstones, and the tendency toward a certain type of crystallization in limestones, are other lithologic features which have been found helpful in correlation. In general each formation is rather well characterized in all parts of the area by lithologic features of these sorts.

Paleontologic Data

In the work of subsurface correlation in this area, it is very doubtful if paleontologic data are as useful as lithologic data. In the first place, even in outcrops fossils are rarely encountered in some systems, and the chances that a drill hole would encounter fossils in those systems are small indeed. Further, just as the fossils typical of an outcropping formation in one area are not always all typical of its equivalent outcropping in another area, so the fossils characteristic of even the nearest outcrop of a formation may not be the fossils typical of its equivalent where it lies below the surface. It is clear, therefore, that unless a formation is definitely known to have consistent paleontologic characteristics over wide areas, paleontological data should be depended upon only in conjunction with other characteristics. These other characteristics are easier to recognize from drill cuttings and in themselves give the sequence of beds and serve as a reliable basis for the use of whatever fossil evidence is obtainable from cuttings or cores.

(2) USE OF SUBSURFACE DATA FOR KNOWLEDGE OF SAND CONDITIONS

Knowledge of the amount of oil remaining in a pay sand and of the nature of the reservoir rock is information without which neither geologist nor operator can confidently advise and act when the questions arise, (1) of the oil in reserve and (2) of choosing and applying an improved method of recovery for a given property. Logs are of but little use in this connection and even cuttings, valuable as they are in other ways, do not give much detailed information as to sand conditions. Cores are the most reliable aid for estimating sand conditions as accurately as desirable for such purposes.

Information from Logs

That even the best kept logs cannot give much information as to the true nature of a pay is evident from the imaginary but typical section through a Pennsylvanian pay sand of this area to be given below under the heading "Use of drill cuttings." Obviously information in that much detail may not be expected from logs compiled on the derrick floor. The driller's log of this same imaginary pay would consider it as a unit and record simply a 35-foot thickness of pay without data as to the relative porosity and the relative amounts of oil contributed by different parts of the pay.

Some striking comparisons have already been given in Chapter II under the heading "Thickness of pay" to show that the logged thickness is not at all proportionate to the amount of production, a condition which indicates that pays are not unit sand bodies uniformly prolific throughout their thickness, but are instead made up of alternating beds of varying thickness, varying porosity, and varying degree of oil saturation.

In the absence of cuttings and cores, the best index of the benefit to be derived from flooding, compressed air, or other methods of improving recovery is not the thickness of pay recorded in driller's logs, but the initial productions of wells, indicating as they do in a very practical way the relative porosity and degree of saturation of the sand.

Logs and sand records may, however, be very useful in supplying supplementary information not obtainable from cuttings and cores, if the depths at which oil and water are encountered and at which they increase are carefully and accurately noted by the driller. Further comment on this point will be made under the heading "Information from cores."

Information From Drill Cuttings

An imaginary but typical section of a Pennsylvanian pay as its character might be determined from study of drill cuttings is given below. Actual data of this sort are included in the Tables of Well Data in a few instances, but are not available for most wells. This section is probably characteristic of Pennsylvanian pays and probably of many older sands through practically all the Illinois fields.

An imaginary section through a Pennsylvanian pay

Bed Number	Character of the pay as seen from drill cuttings	Relative amount oil show	Thickness
1	Medium to fine-grained sand........	Light	4
2	Medium-grained sand	Good	6
3	Fine to medium-grained sand........	Good	3
4	Fine-grained sand..................	Light	5
5	Medium to fine-grained sand........	Good	4
6	Medium to coarse-grained sand......	Very good	5
7	Medium to fine-grained sand........	Good	3
8	Fine-grained sand	Light	5
			Total 35

No "breaks" are included in the above imaginary section, though commonly shale or sandy shale occurs. Shale is often missed in the cuttings. Unless the sands are cemented, the more uniform the size of grain, the more porous the rock, and the larger the grain the greater its flow capacity.

The 35-foot imaginary pay may be separated into four classes: first, bed 6, 5 feet thick, the most prolific; second, bed 2, 6 feet thick; third, beds 3, 5, and 7, total 10 feet thick; and fourth, beds 1, 4, and 8, total 14 feet thick, the least prolific. Actually the fourth grade of sand, two-fifths of the total thickness, would hold and contribute very little oil; whereas the first class of sand, only 5 feet thick, or one-seventh of the total thickness, would probably contribute the greater amount of oil, and contain a very large percentage of the total oil content of the sand as a whole. Undoubtedly shooting would be more beneficial to one grade of sand than to another, but the order of importance of the different grades would probably not be altered, and the subsequent production of this hypothetical well would be made up of unequal amounts of oil from the different

grades of sands. The first grade of sand would contain more oil than the other grades, and would undoubtedly give more oil and a higher percentage of its oil than the other grades. A 50 per cent, or even greater recovery may be obtained from some streaks of sand, and much smaller percentages from other streaks.

To be of value, any estimate of the amount of oil left in a sand must be based on data which permit the elimination from the logged pay thickness of those parts which contain and contribute negligible amounts of oil. Information even as far from complete as the imaginary pay section above, is available for but very few wells in Illinois and does not exist at all for areas large enough to be considered as workable units under any system of improving recovery. And yet if recovery of the remaining oil content on a commercial scale is being considered, just such information as to sand conditions is desired.

From the above discussion of a pay on the basis of its character as determinable from drill cuttings, it is apparent that inadequate though they be, drill cuttings are of much greater service in most ways than logs in obtaining knowledge of sand conditions.

Information from Cores

Diamond-drill or other equally good cores give considerably more reliable data as to sand conditions than do churn-drill cuttings.

Two points in connection with their use should be kept in mind. (1) Conditions vary so markedly from place to place within a pool that several cores—the more the better—are necessary from a given area if much dependence is to be placed on them; and they should be studied in conjunction with the churn-drill logs and sand records. (2) It sometimes happens that a core of a sand may be oil-stained, thus having the appearance of being oil bearing, when as a matter of fact, its pores are filled mainly with salt water, not oil. On this account the depths at which oil and salt water are encountered and at which each increases in the nearby churn-drill holes, are vital to the correct interpretation of diamond-drill cores.

If a number of cores are studied in conjunction with all the available cuttings and logs in a pool (especially if increases of fluid have been carefully noted in the latter) workable estimates can doubtless be made of the average original and present oil content of a sand and of its porosity and character over a unit area, both for the sand as a whole and for its more and less porous parts separately. In Illinois such detailed information is necessary in order to make estimates as to the amount and condition of the oil still remaining in a sand, as a basis for a commercial undertaking.

(3) USE OF SUBSURFACE DATA FOR STRUCTURE DETERMINATION

General Statement

In this area of few outcrops, structure must be determined almost entirely on the basis of data obtained in drilling. Obviously, driller's logs will serve the purpose as well as logs compiled from cuttings and cores, only if the logs have been kept with sufficient accuracy to permit correct correlations.

The structure maps presented in this report are all based on sub-surface data, most of them on elevations of Pennsylvanian sands in wells in the pools. One of the few based on elevations of key beds other than Pennsylvanian sands, Plate XX, is the result of deliberate diamond-drill prospecting for structure.

Comments on the use of Pennsylvanian sands and of other strata as key horizons will follow.

Pennsylvanian Sands as Key Horizons

For two reasons the mapping of structure on the basis of the Pennsylvanian sand elevations is difficult—first, logs are not available for all the wells and many of those that are available are more or less inaccurate; and second, the sands not only vary in thickness but are found at varying levels within a comparatively thick zone. Even if the log data were as detailed and accurate as desired, in most instances contours based directly on the actual sand top of the first sand recorded in each hole in a pool, would not picture the true bedding structure, but rather would represent a combination of the relief produced structurally in the top of the sand, with the original relief resulting from depositional irregularities, both large and small, that affected both thickness and position in the rock section. Of course the minor depositional irregularities could cause only slight and therefore negligible departure from true structure. But in many parts of the Clark County field the depositional irregularities are so large as to introduce important structural errors unless they are recognized and adjustment made accordingly. To choose a single example, the top of the Casey sand "migrates" from above horizon D to below horizon E within the limits of the North Casey pool. The green contours of Plate XXVIII represent the actual relief of the Casey sand top over the North Casey pool, the sand top elevations having been used without adjustment. Obviously these contours do not picture the bedding structure. The purpose of submitting them is to show to what a high degree contours based directly on sand top elevations may fail to represent true bedding structure.

But in all the other structure maps based on Pennsylvanian key horizons, the attempt was made to represent the true structure alone by eliminating relief due to depositional irregularities. The way in which this was done will be of interest: The rock section in every quarter-section of an area whose structure was to be determined was studied in the greatest possible detail to determine the exact horizon to which the majority of the principal sand tops in the area conformed. That horizon was then chosen for contouring. Wherever the top of a sand lay above or below the chosen sand-top horizon, the interval between it and that horizon was determined and then used in adjusting the elevation of the sand top to that horizon. Contours were then drawn on the chosen sand-top horizon, using the actual elevations of all those sand tops that conformed to that horizon, and in addition the adjusted elevations of the remainder. In other words, wherever prominent sands lay at more than one stratigraphic position in the rock section, the intervals between them were determined and then used in reducing their elevations and contours to a common datum. The resulting maps are believed to represent as nearly as can be determined the true Pennsylvanian structure of the various pools.

It was found that the tops of most of the principal Pennsylvanian sands of the Clark County field lay at or close to eight different sand-top horizons. These horizons were chosen for contouring, and were named for convenience horizons "A" to "G," respectively. The various sands whose tops lay at or close to these several sand-top horizons were classified correspondingly as sands "A" to "G." Plate XXIV shows the areas within which sands "A" to "G" were deposited prominently. Plate XXIII shows the approximate stratigraphic

position of each of the Pennsylvanian sand-top horizons (and thus of the prominent Pennsylvanian sands) and serves also as a cross-index to the structure maps based on each of the horizons.

Key Horizons other than Pennsylvanian Sands

Several horizons, some present locally, others everywhere in the area, are suitable key horizons for determining pre-Pennsylvanian structure. Among those used in preparing maps for this report, Plate XXIII shows the approximate stratigraphic position of each of the pre-Pennsylvanian key horizons, and serves also as a cross-index to the various structure maps based on them which have been prepared for this report.

Selection of Key Horizons

Any readily recognizable horizon whose structure or attitude conforms to the structure of the bed or beds about which structural information is desired, and whose character is practically uniform within the area to be worked, will serve as a key horizon.

The geologic history of the area has important bearing on the problem of selecting the key horizon, and should always be kept in mind when choice is being made. For example, the marked deformation which occurred at or near the close of pre-Pennsylvanian time, produced structure in the pre-Pennsylvanian rocks which obviously cannot exist in the Pennsylvanian strata because they had not been deposited at that time. It is partly for this reason that on the uplift a key bed below the Pennsylvanian should be chosen in most instances if true structure of pre-Pennsylvanian strata is sought.

Still another phase of the geologic history which should be kept in mind is the truncation and weathering that followed every period of earth movement. For example, locally the pre-Pennsylvanian formations were subjected to truncation and weathering with the result that fossils and other characteristics were modified and obliterated and that individual beds were locally so changed as not to be definitely recognizable. In such areas, notably near Tuscola, a key bed must be chosen below the weathered limestone.

However, it happens that on the uplift Lower Mississippian and Devonian erosional highs are associated with structural highs as explained elsewhere in this report. For this reason, wherever drilling to the eroded top of the Lower Mississippian or Devonian discloses an erosional high, the probable existence there of a closed structure is indicated. In lieu of actual structure data, such information will serve very well and will reduce the prospecting costs to a very considerable extent.

Core-drilling for Structure

In one locality within the area, the diamond drill has been used to prospect for structure. For the information of those interested in the possibilities of core drilling for this purpose, the results of the operations are described and commented upon below.

CORE-DRILLING OPERATIONS NEAR OAKLAND

At the recommendation of the Illinois State Geological Survey, diamond drilling was begun on a part of the Bellair-Champaign uplift in the vicinity of Oakland, first, to locate exactly the axes of the folds, and, second, to locate domes on these axes. Recommendations[1] were made in an area where doming

[1] Press bulletins of the Illinois State Geological Survey.

was suggested but not proved. Diamond drilling was begun by the Louillo Oil Company of St. Louis, Missouri, who drilled, however, only one hole, but Mr. Charles H. Lewis of Harpster, Ohio, continued the work with nine more diamond-drill holes. The records of these holes are given as detailed logs Nos. 44, 45, 46, 47, 52, 54, 56, 63, 67, and 71.[2] Figures 3 and 4 show fragments of core from hole No. 67. These ten diamond-drill holes partly completed the first step in the program, in that they proved the existence of the folds as predicted, but none of the second-stage drilling was undertaken.

The Sullivan Machinery Company of Chicago did the drilling in 1920, under a contract stipulating 2-inch core and an average depth of approximately 1,000 feet per hole (although the contract allowed depths of 1,200 feet in some holes), at a total cost of about $3.00 per foot. The only additional expense borne by Mr. Lewis was the supplying of core boxes, the Sullivan Machinery Company furnishing coal, water, etc. Three diamond drills were employed, two of the "C-N" type and one of the "P" type.[3]

Prospecting for closures in this area was not completed with the diamond drill, but following up by churn-drill holes proved the existence of the Oakland dome (see Pl. XX). The application of this general method of locating domes is therefore demonstrated. The Oakland dome has not been tested to the deeper horizons, and as yet has not yielded commercial production, but the structural information gained shows within practical limits the behavior of all formations below the Pennsylvanian to and including the St. Peter sandstone, which lies below the Platteville limestone.

The cores obtained by Mr. J. W. Knight of the Sullivan Machinery Company from the ten holes drilled were remarkable. Mr. Knight cored and directly superintended the coring of about 4,000 feet of rock section. The missing parts of the complete section, which included formations varying greatly in character and hardness, were a matter of only a few inches.

ADVANTAGES OF THE DIAMOND DRILL

The advantages found in using the diamond drill for prospecting for structure were as follows: (1) The resulting core showed every variation in the rock section and gave complete detail and accuracy which would have been missing in ordinary samples from drill cuttings; (2) the holes cost no more than churn-drill holes of like depth; (3) casing expense and delays were eliminated; (4) smaller amounts of coal and water were used; (5) a diamond-drill hole that does not reach oil is not considered a dry hole and therefore does not condemn a territory in the minds of operators as might a churn-drill hole of similar depth.

DISADVANTAGES OF THE DIAMOND DRILL

The disadvantages found in using the diamond drill were as follows: (1) Below a depth of 500 or 600 feet the speed of drilling was much slower than that obtained at similar depths with average churn drill machines. No doubt this can be partially remedied by the erection of a derrick that will permit the breaking of rods into longer lengths. It was found, however, that in an average 24-hour day, about 60 feet were drilled in holes approximately 1,000 feet deep. (2) In diamond drilling, the individual ability of the driller is a more important factor than in churn drilling. Parts of cores taken carelessly

[2] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

[3] Full descriptions of these drills are given in the catalogs of the Sullivan Machinery Company, Peoples Gas Bldg., Chicago, Ill.

give no more usable information than ordinary drill cuttings, and in such cases diamond drilling loses a large part of its justification. (3) The hole is not large enough to permit the shutting off of waters penetrated, necessary for the adequate testing of a horizon showing oil. Cores of sands that have their grains oil-coated and retain considerable petroleum, but that are flooded with salt waters and can never produce oil, will show apparent oil-saturation, probably related to "dry-hole-scum" legendary in the oil fields. For example, a core of very porous dolomite (see detailed log No. 67 and fig. 3)[4] was oil-coated for 10 feet, giving a showing of oil, but a churn-drill prospect hole within a few feet of the diamond-drill location found salt water within 1½ to 2 feet of the top of the oil-soaked dolomite, the remaining 8 feet being saturated with salt water. This disadvantage can be eliminated, however, by adapting the diamond drill to holes big enough to permit testing of any such sand encountered. (4) The glacial drift, as much as 200 feet thick locally in this area, was a distinct handicap to the diamond drill due to the inability of this type of machine to go through unconsolidated material efficiently. No doubt this can be remedied.

CONCLUSIONS

The advantages of the diamond drill for the type of work undertaken greatly outweighed the disadvantages, and the adoption of small modifications may overcome the main objections. If a sufficiently large hole can be drilled to enable the production of oil when oil is found, its use will be better justified. As noted by Mr. Frank Edson[5] and others, the diamond drill has been and can be successfully applied in putting down a hole that will produce oil, both when giving a core of the entire rock section and when used to recover only a partial core.

The use of the diamond drill alone to prospect any portion of the uplift is not recommended. The diamond drill should be used in conjunction with the churn drill, as the latter permits a study of water conditions that the diamond drill will permit only with the reduction of its efficiency and an increased cost per foot that might outweigh its other advantages. The successful application of a coring device with the ordinary drilling machine would be ideal. No such devices were used in this investigation, but it is thought that the adoption of such may eliminate or at least narrow the field of the diamond drill.

Certainly the work at Oakland proved the core drill adequate for the location of domes accurately enough to render oil-prospecting on them as sure of success as is wildcatting on geologic structures determined in the customary manner.

Core drilling is especially valuable over the northern part of the uplift where Chester strata are absent and Pennsylvanian commonly either absent or too thin to give production, and where the oil-bearing horizons to be sought therefore lie in or below the Lower Mississippian formations. Unlike Chester and Pennsylvanian sands, in which oil may accumulate due to controls other than doming, the older sands require structural closure for oil accumulation. For this reason, even if new commercial shallow oil pools were to be discovered in Pennsylvanian sands in the northern part of the area, their location would not necessarily indicate structural conditions favorable to oil accumulation in strata of pre-Chester age. Structural closures in the northern part of the uplift must therefore be sought on the basis of structural data on sub-Chester key beds.

[4] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

[5] Edson, Frank A., Diamond drilling for production: Am. Assoc. Petroleum Geologists, vol. 6, No. 2, p. 91, 1922.

CHAPTER V—MISCELLANEOUS NOTES RELATING TO OPERATION

INTRODUCTION

More and more as fewer new pools are found and as the present pools decline, the attention of the operator is turning toward greater efficiency and economy of operation and toward improvement of recovery. The several topics presented in this chapter were chosen for consideration because of their important bearing on such problems. Limitations of space preclude a full systematic statement or discussion of the methods and problems of operation and production in the Clark County field.

WATER IN THE CLARK COUNTY FIELD AND RELATED PROBLEMS

Water troubles of one sort or another encountered in the Clark County field are an especially important factor in lowering the efficiency and increasing the costs of production and operation, and therefore deserve rather thorough consideration. The following introductory paragraphs state the stratigraphic horizons of the water sands and the chemical character of the waters. Incidentally they include also certain more or less significant observations on the association of the water sands with oil sands.

Water Horizons

QUATERNARY

Fresh water is commonly encountered in the sands and gravels of the drift above bed rock.

PENNSYLVANIAN

Salt water sands occur commonly in the Pennsylvanian but are of greatly varying extent, thicknesses, position, porosity, and saturation. Individual bodies vary in area from a few acres in one extreme to several townships in the other.

An interesting condition is that the thickness of salt water sand and the amount of water contributed are about the same where the Pennsylvanian is only one or two hundred feet thick as where it is considerably thicker—even as much as 1,000 feet. This condition is explained by the fact that the water sands are largely restricted to the basal part of the Pennsylvanian section and that this part is little or no thicker where the Pennsylvanian is thick than where it is thin. However, where the Pennsylvanian is more than a thousand feet thick, the amount of salt water sand is in general greater, though as elsewhere the sands lie mostly near the base.

Though many of the Pennsylvanian salt water sands are thin and discontinuous and not uncommonly interbedded with pay streaks, in many parts of the Clark County field a basal "sheet" salt water zone is found rather commonly. This basal zone carries heavy salt water content and closely underlies the oil without very conspicuous breaks between the oil and the water sands. For example, where the Bridgeport sand is present and productive, the water sand

underlies the oil pay so closely that many wells were drilled through the oil into water. But from results of cementing off of water, notably at Millersville, Petty Township, Lawrence County, it is apparent that a definite break must separate the main water horizon from the oil pays even though breaks were not noted in the logs. For when wells in this and other like localities have penetrated the water horizon, if bottom plugging is not tried, large quantities of water must be handled, but cementing these wells a foot or two up into the lowest pay recorded either completely shuts off the water or very greatly reduces it; and, of still greater significance, wells thus cemented have suffered no further encroachment of water even when the leases were put on vacuum.

The fact that hundreds of wells find pays in discontinuous sands both above and below this basal Pennsylvanian salt water sand suggests strongly that a porous "sheet" sand is not a likely place to search for oil. But where such a "sheet" sand is associated with shale breaks and discontinuous sand bodies, oil may be found in these sand bodies lying very closely above the water sand. The areal extent of the basal salt water sand is considerably greater than that of other Pennsylvanian sands, but like them it is confined to the general area of the oil fields.

CHESTER

Salt water sands are common in the Chester, but unlike Pennsylvanian sands, their amounts are roughly proportionate to the total Chester thickness; that is, the thicker the Chester, the more the water encountered, in general. As a rule the thicker, more continuous Chester sands are productive of salt water, and the thinner, notably discontinuous sands are the oil pays. The Buchanan water sand is the most important of the Chester salt water horizons. It has an average thickness of about 150 feet in the pools, and extends continuously over the Lawrence County field and undoubtedly over large areas adjoining Lawrence County on all sides. It is not uncommonly very closely associated with and logged with the basal Pennsylvanian water sand. Its structure conforms with that of oil-producing sands in the Pennsylvanian above and in Chester below. Associated with the Buchanan water sand are "stray" oil pays, in part named Ridgely and Little Buchanan. Where these strays occur they are separated from the Buchanan by a thick shale break. It is considered probable that north of Lawrence County other isolated pays similar to the Ridgely may occur.

LOWER MISSISSIPPIAN

Salt water is encountered at three principal horizons in the Lower Mississippian, known as the "upper water," the "big water," and the "Kinderhook water."

The "upper water" has its source in the upper limestone phase of the Lower Mississippian (specifically in the Spergen, St. Louis, or Ste. Genevieve) and therefore is encountered only in those parts of the area where the upper part of the Lower Mississippian has not been eroded. Its amount, though commonly relatively small, varies greatly from place to place depending on variations in the porosity of the limestones. The stratigraphic position of the water horizons also varies from place to place. Either with or without oil production the occurrence of the "upper water" is very erratic and each individual water zone is of small lateral extent.

The "big water," known best in northern Clark County, lies at about the base of the main Lower Mississippian limestone (that is, immediately below the Spergen), and, depending on the thickness of the Lower Mississippian section,

is found from 250 to 500 feet below its top. This horizon consistently carries great quantities of water through a considerable vertical range, and has always given salt water, never oil, even on domes productive of oil in beds both above and below.

Salt water occurs rather commonly in the Upper Kinderhook over most of the area. Where the Lower Mississippian is extremely thin only the Kinderhook water will be found. The variation in amount of salt water in the Kinderhook is apparently related to variations in the type of sediment, and these in turn to the shoreline of the Kinderhook sea which lay northeast and east of this area in Indiana. The sediments were probably laid down in transitional zones paralleling the shoreline, the sands close to the shoreline, then successively sandy muds, muds and fine sands, muddy calcareous oozes, and, farthest from shore, calcareous oozes. These zones correspond to the westward transition of the Kinderhook from the Knobstone sandstones in Indiana, through the sands and shales of the eastern part of this area to the shales with less sand in the western part of this area, and eventually to shales, shaly limestones, and limestone farther west in Illinois. For practical purposes, the amount of salt water in the Kinderhook might be considered as related to these five general zones as follows: The first, in which water circulation, due to the thick widespread development of porous sand, is practically unrestricted; the second, in which the sands become less and the shales more important, with the result that there is sufficient restriction to circulation to permit slight (non-commercial) oil accumulation, but still considerable water; the third, where shales are still more important, and the sands fewer and fine grained on the whole, a condition promoting enough resistance to circulation to permit oil accumulation in commercial amounts, but permitting also some salt water; the fourth, one of increasing shale, appearance of limy shale and limestone, less and still finer-grained sand, less salt water and less oil (not enough oil to be commercial); fifth, one of rare sands, some shale, and much limestone; and neither water nor oil.

Holes drilled on the Westfield and Martinsville domes probably penetrated Kinderhook of the second and third zones respectively. The drilling on the Westfield dome showed the Kinderhook to be dominantly shale, but partly alternating beds of finer grained sand and shale which gave shows of oil and salt water. As the drilling was in "wet hole" no estimate could be made of the amount of oil, but it was apparently small, though possibly commercial. The Martinsville drilling showed the Kinderhook to be composed of clean shale, sandy shale, and uniform fine-grained sands with shale breaks, the sand (named the Carper) yielding oil with small amounts of associated salt water.

Apparently in a formation of the Kinderhook type, oil production becomes a possibility on domes where the formation no longer includes coarse clean sand bodies in ready fluid communication with fresh or salt water-bearing sands elsewhere. Off domes the formation carries salt water, and the cleaner, thicker, and more continuous the sands, the greater the amount of water.

DEVONIAN-SILURIAN

The Devonian-Silurian carries practically no water in the extreme southern part of the area. Elsewhere it carries two marked horizons of water which increase in importance northward. Regardless of the thickness of the Devonian-Silurian section, two water horizons will be found unless all the Devonian part of the section has been eroded. The upper is in the "crust" immediately underlying the chocolate shale; the lower is the "Niagaran" water, lying from 25 to 250 feet deeper or 600 to 650 feet above the base of the Silurian.

The upper or "crust" water comes from whatever limestones are uppermost in each locality—from limestones considerably younger than Hamilton in the southern part of the area to limestones probably Silurian in age in the extreme northern part where all the undoubted Devonian has been eroded. In general, the crust is less porous southward. In the northern part of the area the upper part of the crust is very porous and saturated with salt water. Southward, tests have gone farther in the crust without striking the big salt water; for instance, at Westfield, about 10 feet, in the Siggins pool, about 20 feet, and on the side of the Martinsville dome about 20 feet. On the Siggins dome immediately under the chocolate shale, this crust horizon has given slight shows of oil and over a small part of the pool has given considerable gas, but salt water is closely associated.

The "Niagaran" water occurs in the sands and sandy dolomites of uncertain correlation that separate the undoubted Devonian and Silurian in the northern part of the area. South of the area, in Crawford County, where these sandy beds are not developed, there is no water at this horizon. Possibly on domes between these two localities intermediate conditions may exist which will allow the "Niagaran" horizon to produce oil.

"TRENTON"

Salt water occurs in the "Trenton" at varying depths and in varying amounts. Often a "hole full of water" will be encountered near the base of the Kimmswick, that is, about 160 feet below the "Trenton" top. The underlying Plattin also contributes water, but the exact nature of its water-bearing beds is not known. Holes off favorable structure usually penetrate the Kimmswick at least 100 feet before getting more than enough water to drill with. But wherever oil is absent, at least small amounts of water are noticed commonly within a very few feet below the top of this limestone. On the Westfield dome, the well highest on structure found no water but contained less gas and less oil than wells that were 25 feet lower structurally, indicating less oil saturation on the top than elsewhere. This horizon appears to be a water-saturated slightly porous horizon of region-wide extent, in which the porosity is so low that the movement of fluids is very restricted, and in the readjustment after folding the invading water and oil failed to saturate the strata over the top of the dome to the extent possible elsewhere.

Character of Waters

Table 14 includes analyses of water from each of the geologic systems known in the area, namely: Ordovician, Devonian-Silurian, Mississippian both Upper and Lower, and Pennsylvanian. The samples were analyzed by the Illinois State Water Survey cooperating in a study of oil-sand waters with the Illinois State Geological Survey.

In general all the waters are apparently "connate" in origin and whatever chemical differences they have are in large part probably the result of differences in mineral content of the reservoir and associated beds. The older waters tend to have higher mineral content. None appears to have been diluted by meteoric waters of the present time, but some variations found are undoubtedly related to the accessibility of the reservoirs to surface waters during previous geological time.

eference number	9	10
ounty	Lawrence	Lawrence
ocation	Sec. 20, Petty Township	Sec. 20, Petty Township
'ell from which water was obta	Mary Wood No. 23 (?)	Mary Wood No. 21
ormation from which water was	Pennsylvanian	Pennsylvanian
ormation productive or non-pro	Productive	Productive
haracter of water-bearing bed	Sand	Sand
haracter of associated beds	Shale	Shale
ate of analysis	May 27, 1919	May 27, 1919
boratory number	41188	41189

otassium	.....	.....
dium	5791.	5595.
nmonium	.....	.....
agnesium	37.13	28.4
lcium	114.8	108.5
umina	80.0	70.0
trate	2.84	2.48
lorine	7205.47	7425.32
lphate	1509.0	920.5
rbonate	.....	.....
sidue	15079.	14236.
on-volatile	0.	0.
ica	0.	0.
carbonate	540.	552.
on	0.	0.
anganese	.....	.....
trite	.....	.....

tassium nitrate	.....	.....
tassium chloride		
dium nitrate		

The waters from sand associated with only shale carry more sulphates than do waters whose reservoir or associated beds are limestones; but they lack minerals noted below as abundant in limestone waters. This is to be expected from the nature of the characteristic accessory minerals in the associated beds.

Potassium is present in the limestone waters of the Devonian-Silurian and Lower Mississippian, but neither in the "Trenton" nor in any of the Chester and Pennsylvanian sandstone waters tested.

Ammonium and magnesium are present in limestone waters; and the former is apparently absent from sandstone waters, and the latter present in but very small amounts. There is some suggestion that the alumina and nitrate content is higher in the waters of oil-producing than of "dry" sands, but the number of analyses is too small to prove the truth of this suggested relation.

Samples Nos. 7, 8, 9, and 10 are all from the same "sand" zone (the Bridgeport) and from adjoining leases, but their mineral content varies markedly. This condition strengthens the suggestion emphasized throughout this report, that the pays are notably discontinuous. Though the Bridgeport sand is the most widespread Pennsylvanian pay sand in Illinois, these marked differences of its salt water in a small area show that locally, at least, there is marked restriction in fluid movement between some of its constituent sand beds.

Water Standing on Productive Sands

It has been the experience to date that water standing on the Pennsylvanian oil-producing sands is of no permanent disadvantage though it is good practice to avoid unnecessary exposure of sands. In normal practice, exposure of the oil-producing sands is necessary as the casing is pulled before the shot. As a rule, there is little difficulty in reseating casing after the shot. The same condition holds for all the Lower Mississippian pays and for the "Trenton"; but some Chester sands seem to be permanently hurt by exposure to water, while the pipe is out of the hole before the shot. On that account it is customary, when at all possible, to shoot Chester sands without removing the casing, by bailing out the fluid until its level is below the casing seat. The reasons for this deleterious effect on some Chester sands cannot be definitely analyzed at this time. It may be that their porosity is of such type that loose fragments are forced into and permanently clog the pores under the head of water from the overlying sands; or perhaps the gas pressure may not be sufficient to prevent this head from forcing considerable water back into the sand.

It is also possible that water standing on these Chester sands may cause precipitation of chemical compounds or deposition of paraffin out of the oil with resultant loss of porosity in the neighborhood of the hole.

The Bridgeport sand is notable in that water may stand on the sand for years without causing permanent damage.

Shut-offs

PENNSYLVANIAN

Even with a small amount of water, Pennsylvanian shales will cave in open hole to a troublesome extent, and thicknesses as small as 150 feet may require a separate shut-off. It is best to figure on at least one shut-off when 150 feet or more of Pennsylvanian is expected.

Any thicknesses of Pennsylvanian up to 500 feet will need at least one shut-off in drilling. If a sand is to be prospected or protected, even 300- to 500-foot thicknesses of Pennsylvanian may need two strings of casing, temporarily at least.

Where the Pennsylvanian is from 500 to 900 feet thick, it will not need any more casing strings than where it is thinner because the amount of water found in the upper part of the thick Pennsylvanian section is not as great as where it is thinner, and consequently there is less trouble in drilling open holes in the upper part of the thick Pennsylvanian. With holes encountering up to 900 feet of Pennsylvanian if no sand is to be prospected or protected it is quite possible to shut off the entire Pennsylvanian for deeper drilling with one string of casing. It is much safer, however, to allow two strings for this thickness as locally too much water may be encountered to make open-hole drilling advisable.

Where the Pennsylvanian is from 900 to 1,900 feet thick it is possible to drill with from one to three strings as the principal sand development is toward the base of the section.

CHESTER (UPPER MISSISSIPPIAN)

Chester water and shut-off conditions are very closely related to the thickness of Chester encountered. Where the Chester is thin the upper thick sand development is usually missing so that with 100-foot or lesser thicknesses, water will not be dangerously troublesome and additional strings of casing may not be necessary. But where as much as 500 feet of Chester is present, two shut-offs may be needed. The tendency of the Chester shales to cave when water is encountered makes drilling in "wet hole" very slow and difficult, and water cannot be carried very far economically. It is best to plan on one string of casing for 100 to 250 feet of Chester; for from 250 to 500 feet it is best to "play safe" and be prepared to use two strings. Locally, structural conditions and variations in porosity of the beds may modify the casing problem.

LOWER MISSISSIPPIAN

Unless pay is to be protected in the upper part of the Lower Mississippian, it is advisable to carry the erratic "upper water" and also the second or "big water" of the Lower Mississippian as far as possible.

Unless the Lower Mississippian is so thick that "wet-hole" drilling through it is too slow to be economical, the "upper" and "big waters" can be carried to the Kinderhook and shut off with the water found there. If the Carper horizon of the Kinderhook is unproductive the same string can be carried to the chocolate shale.

To summarize for the Lower Mississippian, one string of casing will be sufficient for taking care of all the waters encountered unless the speed of drilling is seriously handicapped or unless a pay sand is to be protected.

DEVONIAN-SILURIAN

In the absence of any pay in the Devonian "crust," the "crust" water can be carried to the "Niagaran" water; but both waters will then have to be carried to within approximately 300 feet of the base of the Silurian, where the first good casing seat below the "Niagaran" water will be found. The "Niag-

aran" is the last water to be shut off if drilling is not to be carried below the Kimmswick.

INADVISABLE SHUT-OFFS

There are two parts of a hole where it is a mistake for a wildcat test to shut off the water. The first is in the upper part of the Lower Mississippian limestone. Here water usually occurs at several horizons, separated by non-water-bearing beds, making it inadvisable to shut off the first water found, as more water is usually found a short distance below. On this account, it is better to drill through to the "big water," and not to attempt to go into any possible oil-bearing horizon with the hole dry. Any oil encountered will show itself even with the hole full of water, so that should oil be encountered, it will not be overlooked.

The other part of a hole where water should not be shut off is in the Devonian-Silurian. Even with large quantities of water, it is ordinarily a mistake to shut off the water until the tighter beds of the basal Silurian, suitable for casing seats, are encountered.

SUITABLE CASING SEATS

There is usually no trouble in the Pennsylvanian in seating the casing on the top of the producing or a non-producing sand, or on a "shell." In the Upper Mississippian (Chester), if the prolific water sands of the upper part are present, the numerous "shells" and thick limestones of the lower part offer many ideal casing seats.

Where the St. Louis is present, the Lower Mississippian limestone invariably has allowed successful shut-off. Where no limestones are present, the non-porous, hard sandy shales of the Osage permit a shut-off anywhere desired; and the chocolate shale at the base—strong enough to hold the weight of the casing—is an ideal casing seat.

In the Devonian-Silurian, the dolomites and cherty limestones that underlie the "big Niagaran water" do not offer good casing seats, these strata apparently being sufficiently porous to allow the water to go around the casing seat. It is best to case in the top of the basal 300 feet of the section where shaly and tight limestones are found. The conspicuous fine-grained, lithographic limestone of the Plattin, lying within approximately 200 feet of the "Trenton" top, would probably provide good casing seats for any drilling deeper than the Kimmswick.

In general, with the exception of a few of the Pennsylvanian beds, any of the shales are in themselves strong enough to hold the weight of a casing string, and in addition give ideal conditions for preventing the water from getting around the casing seat.

Corrosion

Probably no casing, tubing, or lead lines are entirely free from corrosion (figs. 7 and 8), but in certain parts of the area, corrosion is so rapid and extreme (see fig. 8) that it is a rather serious problem of oil operation.

The Parker Township pool locally exhibits the most acute corrosion of lead lines, but corrosion of casing and tubing is also serious. Analyses Nos. 1, 2, 3, and 4 in Table 14 show the general character of the waters encountered in this pool; a somewhat detailed account of the corrosion troubles is given in Chapter VI in the description of the Parker pool, and will not be repeated here.

The fact that parts of all pools, including the Parker, are comparatively free from corrosion trouble seems to indicate that the waters even in the same general geological horizon, must vary locally, either as to their amount of mineral content or as to the manner of chemical combinations of the mineral matter, some combinations perhaps being much more strongly corrosive than others. The lower joints of the casing seem to corrode more rapidly than the others. Corrosion is noted both from the inside and the outside of the pipe. It is thought that the outside corrosion causes more trouble than that from the inside because the fluid in the wells commonly does not fill the wells to the level of the casing seats. When the casing is seated in the Pennsylvanian or the top of the Lower Mississippian lime, only Pennsylvanian water can attack it from the outside, unless Lower Mississippian water pumped out of the wells, drips down the out-

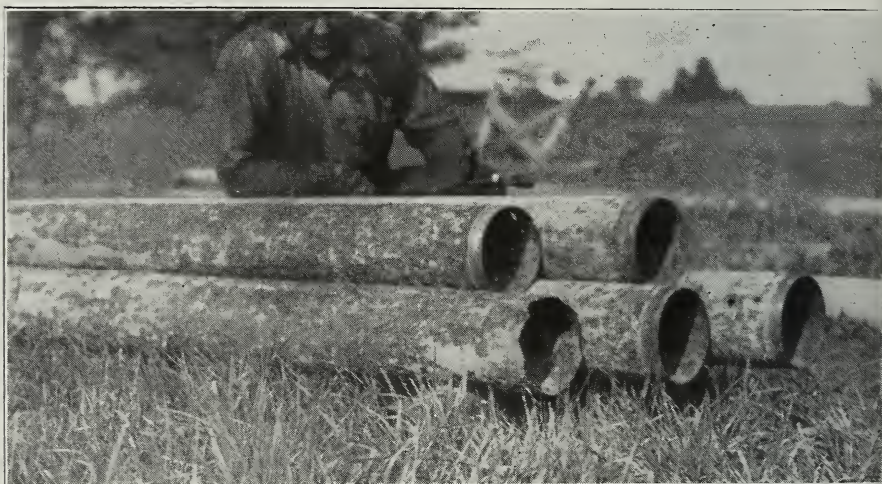


Fig. 7. View of casing, showing typical effects of corrosion. This 6¼-inch casing had been in the Ohio Oil Company's Reeds No. 11 well, sec. 4, Parker Township, Clark County, for 13 years. The corrosion had taken place from the outside, and had been especially active in the threads and just below the collars.

side of the casing from leaky stuffing boxes. The natural Pennsylvanian waters usually contain considerable sulphate, but whether or not such waters still possess their original character after standing behind the casing for many months, as must often happen, is a question. It is not improbable that the chemical changes under such conditions may so alter the character of the water that it will differ greatly from the natural water found in the Pennsylvanian formations. But aside from the question of the character of the water, it appears that the caving of particles of soft rock, especially shale, around some of the casings, probably protects them from corrosion. In this accidental protection of the casing from corrosion in some wells is to be seen an effective means of combating casing corrosion in most wells, namely, "mudding off"[1] the waters.

[1]Tough, F. H., Williston, S. H., and Savage, T. E., Experiments in water control in the Flat Rock pool, Crawford County: Illinois State Geol. Survey Bull. 40, p. 132, 1919.

Data on this problem were gathered by Mr. R. Van A. Mills of the United States Bureau of Mines and are incorporated in a bulletin[2] of that bureau. Figure 8 pictures an extreme example, but illustrates the general nature of the effects of pipe-corrosion.

Trials have been made of different sorts of pipe in an attempt to find some kind resistant to corrosion, as described in detail in Chapter VI in the discussion of the Parker pool. Cast-iron pipe gave the best result, but by no means solves the problem.

Although taken as a whole the Clark County field has to date required a small percentage of replaced casing, the evidence shows corrosion to be active

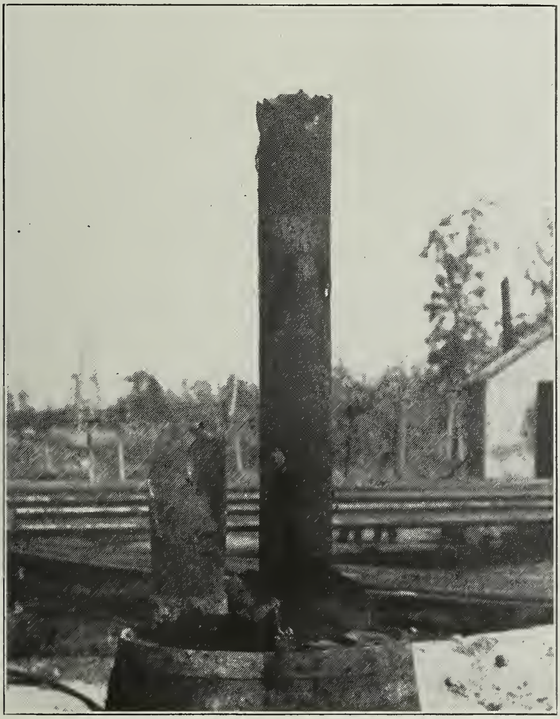


Fig. 8. View of casing, showing extreme effects of corrosion. This casing was taken from a well on the Silurian Oil Company's Coombs lease in Petty Township, Lawrence County, and had been corroded by the Bridgeport sand water.

in widely separated parts of the field, and it is probably justifiable to consider that the wells so far not directly affected may shortly or eventually need new casing strings to protect the producing sands. Wells whose production has fallen below half a barrel per day are likely to have their natural lives shortened by failure of the casing now in the hole, for the cost of running new strings of casing, or merely replacing the corroded joints, would in most instances be prohibitive; and further, it is sometimes impossible to reseat the pipe securely after

[2]Mills, R. Van A., Protection of oil and gas field equipment against corrosion: U. S. Bur. Mines Bull. 233, 1925.

it has been pulled, with the result that an increasing amount of water reaches the sand and may lower its production seriously.

Salt Water in the Producing Zones

Water is found in and intimately associated with the producing sands in the Clark County field, whereas in Crawford and Lawrence counties the shallow producing sands usually carry salt water closely underlying the oil of the upper part of the sands.

In the latter counties many wells have entered so far into the water-saturated portion of the sand that considerable amounts of water must be handled, and corrosion is increased. Under such conditions, cementing off of bottom water has given very satisfactory results in different parts of Crawford and Lawrence counties. It has been found there that not only can the amount of water handled be reduced by such cementing, but the shutting off of water brings an increased production of oil. Work of this kind at Flat Rock is described in Bulletin 40.[3] More recent work, as yet not published, has given excellent results in the vicinity of Millersville, Lawrence County, on the Mary Woods and Lewis[4] leases of the Indian Refining Company, and more recently on the Coombs lease of the Silurian Oil Company. The sands cemented were all Bridgeport sands.

In the Clark County field, conditions rather closely comparable to the bottom-water conditions of Lawrence and Crawford counties, described above, are found in the Bellair pool and in the Johnson Township production. There, individual leases can be and have been helped by the cementing off of bottom water, both by reducing the amount of water handled and also by reducing corrosion. But taking the Clark County field as a whole, the area is small in which producing conditions may be improved by bottom-water cementing.

Water is very closely associated with the oil in the Lower Mississippian limestone of the Parker Township pool, and very large quantities of water have been and are being handled to obtain relatively small amounts of oil. But this water is not "bottom water" of the type found in Lawrence and Crawford counties, as may be deduced from its history, which is briefly as follows: When the Parker pool was originally "drilled up," the wells, even those adjoining each other, penetrated the Lower Mississippian limestone for widely varying distances before striking salt water; but very few wells went more than about 75 feet into the lime before reaching water. Gradually, however, the depth to which wells could be drilled into the lime seemed to increase—in other words, waters at intermediate parts of the upper portion of the lime were reduced by pumping—until now production is obtained over 200 feet in the Lower Missis-

3Tough, F. H., Williston, S. H., and Savage, T. E., Experiments in water control in the Flat Rock pool, Crawford County: Illinois State Geol. Survey Bull. 40, 1919.

4The cementing work on the Lewis No. 12 well of the Indian Refining Company at Petrolia, Petty Township, Lawrence County, is of special interest. The well originally or later was drilled into the water, and after seven or eight years the amount of oil available became very small. The amount of water handled continued to increase until at the end of twelve years, with the working barrel near the bottom, it was impossible to keep pace with the water. With the working barrel 100 feet above the bottom it was possible to pump off the extra water each day, but no oil was being obtained. This well was then cemented by putting a plug of cement in the bottom to within a foot or so of the last pay as logged, and immediately after the 10-day period for setting had elapsed the well pumped only about five barrels of water per day. At the end of two weeks' pumping the well gave ⅛ of a barrel of oil and five barrels of water per day, as contrasted with 275 barrels of water and no oil before cementing, and after less than a year's daily pumping the oil recovery increased to about 3 barrels per day with little or no increase in water.

sippian limestone and the water is handled in open hole. That the oil occurs in recurring pays in the oölitic limestone, rather than continuously suggests that the water occurs in similarly disconnected parts of the limestone. And further, the individual pockets of water are as erratic as are the individual pockets of oil, taking the pool as a whole.

It appears to be established, then, that enough water has been pumped along with the oil since 1905, to reduce greatly the total amount of water in the Lower Mississippian limestone, thus permitting the open-hole development of still lower pays. It is probable also that the general water horizon in the upper part of this limestone has been lowered and that considerable oil has followed the upper surface of the water down into lower parts of the lime.

IMPROVED RECOVERY METHODS

Three methods of improving recovery and thereby increasing lease profits have been tried in the Clark County field to varying extent and with varying degrees of success. Of the three, the installation of the suction pump or vacuum has to date been the most widely applied and the most effective, but natural-gas gasoline plants have also proved very profitable in most instances. Compressed gas or air has been comparatively little used for reasons that will be explained below.

No attempt is made in this report to discuss the subject of improved recovery methods in an exhaustive way, but merely to point out and briefly comment upon such methods as are in use or as have been tried.

Table 15.—*Production from individual leases before and after the installation of the gas pump*

Pool	Number of wells	Lease production in barrels for the month of April				Remarks
		1917	1918	1919	1920	
Siggins (Union Township).	29	838	725	704	825	First well on vacuum April, 1919; 8, September, 1919; 11, May, 1920.
Siggins (Union Township).	17	511	650	877	1298	Four wells on vacuum April, 1919; 11, 1920; some wells deepened.
Johnson Township..	41	9219	6898	7231	6080	First well on vacuum May, 1917; 23, 1920; some wells deepened.
Casey Township ..	17	390	586	485	378	First well on vacuum 1917; 16, 1920.
Westfield (Parker Township)	20	465	113	305	544	First well on vacuum 1918; 5 new wells drilled in 1917.

Gas Pump[5]

The first installation of gas pumps in the Clark County field was in 1913 in the Westfield pool. Except for the North Casey and Martinsville pools, practically the whole field is now on vacuum, and had been so for from 4 to 4½ years on the average in the summer of 1922. Over the whole field the age of wells averaged 10 to 10½ years when the vacuum was installed.

For two reasons no clean-cut comparisons can be made to show the exact increase of production due to the vacuum: First, when vacuum was introduced on a lease, only a few wells (usually line wells) were put on suction at the start, and as much as two years or more commonly elapsed before the whole lease was on suction. Second, in addition to installation of vacuum, on most of the leases the wells have been deepened to lower pay streaks in the sand zone. Though these two reasons make it impossible to isolate the increases in production due to the vacuum, the examples given in Table 15 will serve to show in a general way the effect of vacuum on lease production.

Installation of vacuum has also caused a decrease in the Baumé gravity of the crude oil produced in the Clark County field. However, the decrease though noticeable over a period of years, is relatively very slight.

The first 19 samples whose analyses are given in Table 3, all taken after the wells had been on the gas pump from one to six years, have an average Baumé gravity of 31.9°. Unfortunately, no corresponding analyses are available to show the gravity before the gas pump was introduced. But progressive tests made by one of the companies in Lawrence County confirm the statement that a lowering of the Baumé gravity follows the use of the gas pump. The action of the vacuum pump is to induce the release of gases held under very slight pressure in the oil and also to cause hydrocarbons which were in the liquid form before the installation of the vacuum, to enter into the gases as vapor. Thus, though the gravity of the oil was lowered after the installation of vacuum, the amount of gas obtained was somewhat increased.

Natural-gas Gasoline Plants[6]

Nine casing-head gasoline plants have been installed in the Clark County field: one in Licking Township (on the Smith farm, sec. 11, O. C. Sutherland and Indian Refining Company); one in Johnson Township (Southern Oil Company); two in Casey Township (M. Crouch and T. J. McDaniel farms, Ohio Oil Company); four in Union Township (three, M. E. Kite and Walker farms, Ohio Oil Company; one, Bell Brothers); and one in Parker Township (Pinnell farm, sec. 6, American Oil and Development Company). (See fig. 9.) The plants have not all been in continuous operation. Most of them are small, averaging from 150 to 200 gallons of gasoline per day with a total potential capacity of about 400 gallons if a sufficient amount of gasoline-bearing gas were available. The exception is the M. E. Kite plant of the Ohio Oil Company which is the biggest casing-head gasoline plant in Illinois. This plant produces about 1,000 gallons of gasoline per day during the summer months, and from 1,200 to 1,500 gallons per day during the winter months. The gas for the M. E. Kite plant is obtained by six suction pumps, four Patten Brothers gas pumps (single) and two Ingersoll-Rand pumps (twin). The plant is operated by a 190-H. P. gas engine. The gas from the pumps goes through scale-catchers

---

[5] Variously known also as "suction," "suction pump" or "vacuum."

[6] Sometimes called casing-head gasoline plants.

(made of 12-foot lengths of 10-inch pipe) into a cylindrical tank scale-catcher which acts also as a small reservoir equalizer. The gas is then taken into the low pressure side of the compressor (Ingersoll-Rand two-stage) and there compressed to approximately 70 pounds per square inch. This low-pressure gas passes through approximately 750 feet of 2-inch cooling coils (water cooled) in the spray tower, and on its return passes through the low-pressure gasoline reservoir tank before entering the high-pressure side of the compressor. The high-pressure cylinder compresses to from 240 to 250 pounds per square inch, and the gas is cooled through about 1,325 feet of 2-inch cooling coils. The gravity of the low-pressure gasoline recovered is approximately 60° to 62° Baumé, and of the high pressure approximately 84° to 86° Baumé. In summer the high-pressure coils recover about twice as much gasoline as do the low-pressure, but in winter the recovery is about equal. This plant, like all plants in this field, is a "straight compression plant," two-stage compression with high- and low-pressure coils being universally used.

Fig. 9. View of the Ohio Oil Company's natural-gas gasoline plant on the McDaniel farm, Casey Township, Clark County.

The plant operated by the American Oil and Development Company has a gas washer between the gathering line and the compressors. All the others have only simple scale catchers. The number of wells attached to the different plants varies. In the case of the M. E. Kite plant the number exceeds 350 wells, and in some of the smaller plants, of wells attached to the suction, 80 wells. The amount of gasoline recovered per 1,000 cubic feet of gas runs from about one gallon to 1¾ gallons, the average being under 1½ gallons. All the plants show greater recovery during the winter months when it is possible to cool the gases more effectively and thus condense a greater proportion of vapor out of the gas. The installation of additional cooling apparatus, necessary for the recovery of more of the vapor content of the gas during summer months, has not been demonstrated to be practical. The amount of gas being obtained from individual wells ranges approximately from 500 to 4,000 cubic feet per day per well, the average per well per day being approximately between 1,000 and 1,500 cubic feet.

Compressed Air or Gas

Experiments in the use of compressed air or gas had been made previous to 1921, but in that year the first plants were installed for the thorough testing of the process. Compressed air vitiates the gas, and as the supply of gas for fuel is low, compressed air is not in favor, and will have little application in the future. However, compressed gas has been pumped back into Pennsylvanian sands, and a decided increase in production has resulted. The process is still in the experimental stage in this field and no exact details are available for publication at this time. The method has not been sufficiently tested to demonstrate definitely that it is now profitable, but there is no doubt that production of leases can be increased and that a large part of the Clark County field will react profitably to such a method in the future. In parts of the field, introduction of compressed gas will depend on the practicability of washing the gas free from considerable of its sulphur compounds, which are very injurious to the compressors. One installation, which compressed the gas direct from the suction lines, ran only three months before the gas ruined the compressor.

LLINO

CHAPTER VI—DESCRIPTION OF POOLS

WESTFIELD OR PARKER POOL

Introduction

The Westfield pool lies largely in Parker Township, Clark County. Plates I and XXI show its position and extent, and Table 2 states its productive area; the number, depth, spacing, age, average initial and daily production, and average pay thickness of its wells; the number of abandonments to date; and the estimated total production and recovery per acre to date. Plates XXII (a) and XXVI show the locations of its wells, and its structure. Plates XIII and XIV are cross-sections of the southeastern and northern parts of the pool, respectively. The pool is located on a large and well-defined dome, the structure being demonstrated for both the Pennsylvanian and the pre-Pennsylvanian formations. Plate XXV is a columnar section showing the character and thickness of the rock strata in the area. Plate V is a generalized east-west section showing the structural relations of the pool.

In 1920 approximately 1,600 wells were producing oil in the Westfield pool. The daily production of the average lease well varied from 1/10 of a barrel to about 4 barrels. Figures from 33 per cent of the wells indicated an average of about one barrel per day per well as stated in Table 2, but most of the wells were producing about half a barrel per day or less.

The maximum recovery per acre known for the Westfield pool was more than twice the average figure of 2,080 barrels per acre, stated in Table 2.

The character of the oil from each of the producing horizons is indicated by the four analyses given in Table 3 (samples Nos. 1, 2, 3, and 4).

Sands

The productive sands of the Westfield pool are the "gas sand" (McLeansboro) of the Pennsylvanian; the "Westfield lime" (commonly Spergen-Salem, but probably the St. Louis and Osage in some instances) of the Lower Mississippian; and the "Trenton" (Kimmswick) of the Ordovician. The Lower Mississippian production has been the most important. Plate XXV, the columnar section for the Westfield pool, shows the position and character of the principal sands.

PENNSYLVANIAN

"GAS SAND"

The "gas sand" zone of the Westfield pool is part of the McLeansboro formation. Any sand found between a depth of 300 feet and the top of the lime at approximately 300 feet, was classed as "gas sand" by the drillers. It will be seen from the Tables of Well Data that the occurrence of sand is erratic. In and near the pool the top of this sand corresponds to horizon B (see Plate XXIII) and lies from 60 to 150 feet above the unconformable top of the Lower Mississippian. Plate XIII, a cross-section of the southeast flank of the Parker dome, illustrates these relations.

The "gas sand" produced oil in parts of secs. 33 and 34, Westfield Township, secs. 3, 6, 7, 18, 19, 20, 21, 29, and 30, Parker Township, and secs. 7, 18, and 19, Hutton Township. In the central part of the pool sand at this general zone produced small amounts of gas and no oil. The map, Plate XXVI, showing in green the wells producing from the "gas sand," covers all the above-mentioned area except sec. 34, Westfield Township, and sec. 3, Parker Township. Northeast from the main pool, in secs. 22 and 27, Westfield Township, sand lying close to or at sand-top horizon C supplied the few gas wells found there.

The depths to the top of the "gas sand" vary from 210 to about 310 feet in and near the pool, and the elevation of the top (Pl. XXVI) varies from about 450 to about 350 feet above sea level. Oil was produced through a range in elevation of about 60 feet, that is from 410 to 350 feet above sea level, approximately. Gas occurred above the 410-foot level. The thickness of the "gas sand" varies from 15 feet or less in the central part of the pool where the interval between its top and the Lower Mississippian is at a minimum, to about 50 or 60 feet in Hutton and southwest Parker townships, where it produced oil and where the interval between its top and the Lower Mississippian is considerably greater (compare green and red contours, Plate XXVI). Incomplete data indicate the average logged thickness of pay to be 37 feet.

The "gas sand" zone may be described as sandy shale over most of the pool or perhaps better as shale with erratic streaks of shaly sand. In the sand streaks found in the central, structurally highest part of the pool, considerable quantities of gas were encountered, but no commercial oil production. Purer sand streaks 30 to 60 feet thick occur over considerable areas toward the edges of the pool at this horizon high enough on structure to produce oil. The wells were small, most of them considerably below the average for the pool, which was 38 barrels, initial; and although some wells gave an initial flush as high as 100 barrels, in most instances such wells declined more rapidly than wells of equal flush production in the Lower Mississippian pay. The percentage of these wells now abandoned is large. Though the "gas sand" wells were less prolific than the average Mississippian lime well, they commonly gave better shows of free oil when "drilled in."

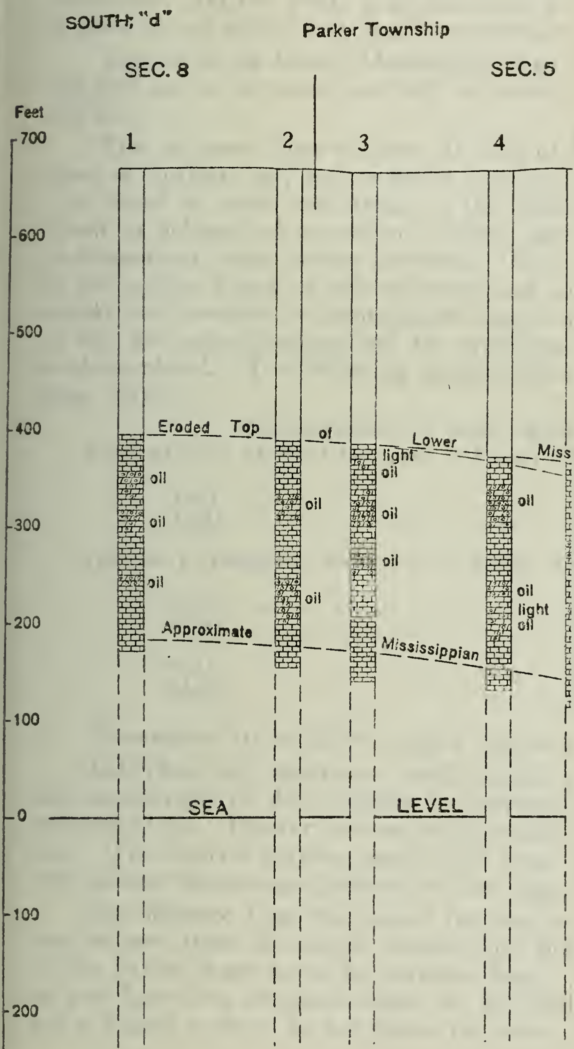
Very little salt water is associated with the "gas sand" in the vicinity of the Westfield pool, and even edge wells drilled completely through it did not encounter excess salt water.

ANOTHER PENNSYLVANIAN SAND

Around the edges of the Westfield pool, low on the flanks of the Parker dome, particularly northeast in secs. 22 and 27, Westfield Township, a sand is found immediately overlying the Lower Mississippian lime which falls below horizon C and in places possibly as low as horizon D. It carries small quantities of oil or gas in some places, but is in general probably too far removed from the influence of the doming to carry important production.

LOWER MISSISSIPPIAN (WESTFIELD LIME)

The Lower Mississippian limestone (the "Westfield lime" of the driller) is the main producing horizon of the Westfield pool. It is in unconformable contact with the overlying Pennsylvanian. In most places, beds of Spergen age are uppermost, but in others remnants of St. Louis age (probably not more


SOUTH; "d"
Parker Township
SEC. 8
SEC. 5
Feet
700
600
500
400
300
200
100
0
100
200
1
2
3
4
Eroded Top of Lower Miss
Approximate Mississippian
oil
light oil
SEA
LEVEL

than 60 feet thick at the maximum) overlie the Spergen. The Spergen is approximately 200 feet thick, is all limestone, and includes a considerable number of more or less oölitic beds that have been altered.

The top of the Lower Mississippian lime varies in depth from 275 to about 350 feet, and in elevation from 400 to about 250 feet above sea-level (see Plate XXVI).

The oil comes from the first 200 feet of limestone—most of it from limestone of Spergen age, but probably some from overlying St. Louis limestone. It is found in many thin streaks in this 200-foot thickness, occurring to some extent in dolomitized crystalline, slightly oölitic limestone, but more generally in dolomitized oölitic impure limestone. The range in porosity is very wide due to the varying degree of dolomitization and oölitic content. The oil-producing streaks are brownish to cream-colored lime, the color varying with the amount of oil; the non-oil-bearing and the water-bearing limes are commonly bluish to drab-colored. The following analyses show the extent of dolomitization in some "pays":

Partial analyses of some "Westfield lime" pays

From well No. 59, Reed farm, sec. 9, Parker Township:

	Per cent
CaO	31.33
MgO	9.25

From N. P. Dougherty farm, sec. 10, Parker Township; two samples:

	Per cent
CaO	39.5
MgO	14.4
CaO	52.74
MgO	17.90

No analyses are available to show the extent of silicification.

Individual pay streaks are rarely logged as much as 20 feet in thickness, and considerable of that thickness is comparatively tight, providing only small amounts of oil. The very porous streaks rarely reach or exceed 10 feet in thickness. The interval between pays varies from 10 up to 100 feet. Incomplete data indicate the average thickness of lime logged as pay to be 41 feet.

The distance from the top of the lime to the first pay streak varies, as may be seen from the typical cross-section, Plate XIV, taken from the center of the Parker dome down its northern flank. In Westfield Township, where no pays have been developed below the first 100 feet in the lime, the top of the pay is logged as 20 to 50 feet below the top of the lime.

In secs. 3 and 4, Parker Township, where also no pay is found below the first 100 feet, the top of the first pay is in some places the top of the lime, but elsewhere lies at varying distances below the top, up to a maximum of 50 feet—most wells showing it about 15 feet in. The best part of the pay is found from 5 to 90 feet below its top, but most commonly from 10 to 15 feet.

In secs. 5, 6, 7, and 8, Parker Township, pays are found in the first 200 feet of the lime. Here the total thicknesses of pay are logged from 30 to 180 feet. Locally in these sections the top of the lime is also the top of the first pay, but elsewhere the distance in from the top of the lime to the first pay varies up to a maximum of 80 feet. The average distance is 20 to 25 feet. The best part of the pay lies about 20 feet below the top of the pay in most instances, but elsewhere is logged at varying distances below up to a maximum of 100 feet.

In secs. 9 and 16, Parker Township, the pays are with very few exceptions restricted to the first 100 feet of lime; but in general the top of the pay is somewhat farther in the lime than it is in the sections just described.

In secs. 17, 18, 19, and 20, Parker Township, where the lime pays are distributed through a thickness of approximately 200 feet, the first pay is closer to the top of the lime, being on the average from 5 to 15 feet in. In secs. 21, 29, and 30, Parker Township, where the lime pay is confined to the upper 100 feet, the pay occurs farther below the top of the lime than in the two previously noted instances.

In secs. 7, 18, and 19, T. 11 N., R. 11 E., Hutton Township, production is restricted to the first 100 feet of the lime, and the top of the pay is farther in than the field average.

The pays in the second 100 feet of the lime are relatively small unless they are associated with crevices. The dolomitized oölites are less porous than those in the upper 100 feet. Crevices are sometimes encountered in drilling and some wells shot into crevices.

The close association of salt water with the Lower Mississippian oil production in the Parker pool necessitates the pumping of large quantities of water with the oil. When the pool was first drilled up, large quantities of salt water were very commonly encountered below the first two pay streaks, or about 75 feet in from the top of the Lower Mississippian lime; and in parts of the field water was found at even lesser depths in the lime. Apparently the water occurs as does the oil, at many separate thin horizons in the limestone, although the basal part of the limestone seems generally saturated with salt water. It is to be expected that the conditions of porosity that would permit oil to occur in multiple streaks through this limestone would also permit water to occur similarly.

Since the original drilling up of the field, the water associated with the upper pays has been to a great extent exhausted, so that the deepening of the wells 75 to 125 feet farther into the limestone is practicable. The upper waters vary in quantity, but are now successfully handled from wells that have as much as 200 feet of limestone in open hole. However, it has been found necessary to plug off the water from the basal part of the lime at the bottom of some wells.

Analyses of the Lower Mississippian limestone water associated with the oil are given in Table 14.

ORDOVICIAN

"TRENTON" LIME

The "Trenton" (Kimmswick), the deepest oil-bearing sand known in the Parker pool, has not been vigorously developed on account of its great depth and the smallness of the resulting wells. Its top lies at about 2,270 feet and its base at about 2,400 feet. Plate XXVI shows in black the holes that have reached the "Trenton" in the Parker pool.

The pay is rather pure, crystalline limestone of slightly variable porosity. A thickness of as much as 140 feet of Kimmswick has been found to carry oil, and the latest "Trenton" well, McFarland No. 1, NE. 1/4 SW. 1/4 sec. 19, T. 10 N., R. 13 W., in the Martinsville pool, suggests that even greater thicknesses may carry oil locally. The extreme upper part of the "Trenton" is usually less porous and in general the uppermost 5 to 40 feet carries no oil.

The lower part is somewhat more porous, probably due to its slightly greater crystallinity and magnesium carbonate content as well as to the presence of small amounts of sand. The "Trenton" horizon may be considered essentially as a 125-foot pay, contributing some oil throughout its thickness, but any 15 or 20 feet of it, with the possible exception of the lower part, would not supply enough oil to make a commercial well.

Most of the "Trenton" drilling to date has been on "edge leases" in an attempt to offset the drop in the shallow production in such localities, and thus most of the tests have not been well located structurally (see Plate XXVI). The present "Trenton" wells are therefore considerably below the average that could be expected in locations structurally more favorable. Only eleven producing wells have been drilled to date; but the black contours of Plate XXVI indicate the existence of a considerable additional area within which the "Trenton" lies as high as or higher than in these wells and where it therefore undoubtedly will produce oil. The best wells drilled to date have a considerable flush after the shot, but drop in two or three months to 10 or 12 barrels per day on the pump. From this point the decline is very slow, some wells making 7 or 8 barrels at the end of two years.

Where the "Trenton" contains oil, the wells have little water. Elsewhere water appears in small quantities, not enough to drill with at first, but usually enough for drilling within about 100 feet; in no instance was the Plattin reached without the Kimmswick supplying enough water to drill with. The amount of water, like the oil, will vary with the porosity of the Kimmswick and also with structural conditions, but seems somewhat in excess of the amount of oil the wells will make naturally. The water found in the "Trenton" is called "blue lick" by the drillers.

OTHER POSSIBLE HORIZONS

The central or limestone member of the Maquoketa is another horizon in the Ordovician which has given good shows of oil in Parker Township. In a single instance, namely the Ohio Oil Company's G. A. Fuller No. 24, Account 2, in the SE. ¼ sec. 5, T. 11 N., R. 14 W., it has produced enough oil to make a small well. The base of this "sand" (called the "Clinton" by the Illinois drillers), is approximately 120 feet above the top of the "Trenton." It is apparently not present in central Crawford County, but in Clark County and northward its thickness varies from 20 to 60 feet. It is crystalline limestone, yellowish to blue in color, and contains some white cherty material. As no water occurs between this horizon and the "Trenton" it is probable that some wells will produce from both these horizons.

Another possible producing horizon in the Ordovician may lie below the Plattin at a horizon corresponding to a pay horizon in Ohio which Dr. Panyity[1] correlates as Stones River. Drill cuttings, notably those from the K. and E. Young No. 79 well, indicate the presence in the lower Plattin of considerable bituminous matter, which might be a source of oil; and if a reservoir rock of impure limestone or sand exists in the limestone below the Kimmswick and above the St. Peter sandstone, an accumulation of oil in the reservoir becomes a possibility. The formations in this part of the section deserve one test on demonstrated closed structure.

The St. Peter is not considered favorable on account of lack of shale in adjacent formations and its "sheet sand" character.

[1]Panyity, L. S., Oil and gas bearing horizons of the Ordovician system in Ohio: Bull. Amer. Assoc. Pet. Geologists, vol. 5, pp. 609-619, 1921.

Structure

Structural contours (Pl. XXVI) based on the several important pay horizons in the Parker pool, show that the pool is located on a broad, well defined dome, which is known as the Parker dome. The "gas sand," the Lower Mississippian lime, and the "Trenton" structure are each discussed separately below.

"GAS SAND" STRUCTURE

Insufficiency of data for the "gas sand" and the erratic nature of its development made the use of its top as a datum level impractical in parts of the pool. However, conditions permitted the contouring of sand-top horizon B (Pl. XXIII) over the southern half of the pool, as shown in green on Plate XXVI. The sand tops that varied from horizon B were adjusted to that level as explained in Chapter IV. Although the data for the north half are incomplete, they seem to indicate that probably the closure is not much in excess of 125 feet.

The range in sand-top elevation through which oil production is obtained from the "gas sand" on the Parker dome is about 60 feet. As the distribution of the "gas sand" wells and dry holes (Pl. XXVI) shows, production is confined to a strip varying in width from half a mile on the western flank of the dome (where the dip of the bedding is relatively steep) to three-fourths of a mile on the eastern flank (where the strata dip less steeply).

LOWER MISSISSIPPIAN STRUCTURE

The top of the Lower Mississippian limestone (horizon L, Pl. XXIII) is easily recognized and commonly logged, making it the best basis on which to study conditions in the pool, especially as its topography is indicative of the bedding structure.

The contours submitted on Plate XXVI represent the topography of the eroded Lower Mississippian surface. Some evidence of "pot holes" (sink holes) was found, but only the largest ones are shown, as too much detail would only tend to obscure the more important features of the unconformable surface, particularly its relationship to structure.

Over the central part of the pool (that is, over most of secs. 5, 7, 8, 9, 17, 18, and parts of 19, 20, 29, and 30, all of Parker Township), the total thickness of the Lower Mississippian varies only about 10 feet, from 880 to 890, total thickness; but on all sides of this central portion of uniformly thick Lower Mississippian, the strata thicken rather abruptly at least 110 feet to a total of 990 feet at or near the edge of production. Consequently, whereas in the central part of the pool the top of the lime is approximately conformable with the Mississippian bedding and its contours for all practical purposes represent Mississippian structure, in the outlying parts of the pool the top of the lime and the bedding diverge rather sharply, so that the topographic relief shown by the contours is considerably less than the structural relief. These relations are illustrated in cross-section d-e, Plate XIV, in considerable detail; and in structural section L-M, Plate V, in less detail.

Within the area of structural closure, Pennsylvanian bedding shows a closure of about 125 feet and the Lower Mississippian bedding about 290 feet, the ratio being 1:2.6. This ratio increases at localities more removed from closures, the extreme being about 1:9. Over the northeast part of the dome

(where control data are available) the closure on the eroded top of the Lower Mississippian limestone (red contours, Pl. XXVI) is about 180 feet (from 400 feet above sea-level to 220 feet above sea-level) and the closure on the Mississippian bedding is about 290 feet, the difference (110 feet) being due to the thickening of the Mississippian limestone marginal to the structure, as noted above.

In general the Lower Mississippian limestone produces on those parts of the dome where its top lies at elevations from 400 to 300 feet above sea-level. The pays found in the marginal areas of the structure, where the top of the lime lies at about 300 feet above sea-level, are confined to the upper 100 feet of the lime; but it is obvious that since the lime is 110 feet thicker in these marginal areas than in the central part of the structure, the 100-foot pay zone of the marginal areas must lie stratigraphically 110 feet higher than the upper 100-foot pay zone of the central part. Or in other words, the edge limestone production is obtained from beds that are not represented in the central portion of the structure (see Plate XIV). Production from individual pay streaks or stratigraphic zones seems limited to a maximum range in elevation of about 75 feet.

Pays in the second 100 feet of the Lower Mississippian limestone are confined to the central part of the structure. No pays below the first 100 feet have been noted where the top of the Lower Mississippian lies below approximately 325 feet above sea-level, that is about 75 feet below its highest elevation, or in terms of structure, probably a true bedding range of approximately 65 to 75 feet. Further, wherever the lime is thicker than 880 feet, even though its top may lie above the 325-foot level, no pays are found below the first 100 feet.

Locally the pay zones occur at regular and consistent depths in the lime. (See the Tables of Well Data.) The wells on the higher parts of the structure have the most pay streaks (for example, see Pl. XIV) and the streaks are more prolific there than elsewhere. The most porous part of each streak varies, even locally, in porosity and in its position in the rock section. In the central portion of the pool the exact position of the best pays varies somewhat, but at least three places out of the total in the first 200 feet consistently give considerable oil. Toward the edges of the pool (that is, toward the thicker and topographically lower limestone) the pay is confined to one or at most two pay streaks in the first 100 feet of the limestone.

Undoubtedly pay streaks or porous horizons are to some extent continuous, so that some individual pays in the central part of the pool pass to stratigraphically higher beds (absent in the central portion) towards the edges.

Many of the pays of the upper 100 feet are much dolomitized or altered, especially those that lie at or close to the eroded top of the Lower Mississippian. The pays in the second 100 feet are dolomitized or altered to but a slight extent and are notably less prolific than the upper pays, being equally as good only when jointed or creviced. The subjection of these limestones to surface conditions of erosion and weathering during pre-Pennsylvanian time undoubtedly was the cause of the dolomitization, although the altering may have been augmented somewhat since the Pennsylvanian cap was deposited. Water working through limestone ordinarily tends to follow the bedding and the most oölitic beds, but in the Parker area the limestones were so thick and their oölitic beds so variable that the proximity, contour, and nature of the surface locally had more influence on the formation of continuous porous streaks than had the bedding, as

shown by the fact that in parts of the pool the pays "carry across" the bedding, as noted in the preceding paragraph. Thus the topography developed by erosion of the top of the Lower Mississippian has a direct relation to commercial oil production, and although the topography of the Lower Mississippian top is directly related to the original structure of the Lower Mississippian, it was the erosion of the structure that directly controlled the commercial accumulation rather than the structure itself. The red contours on Plate XXVI, showing as they do the relief in the top of the lime, are therefore more desirable than true structure contours even were the data sufficient to permit the latter being represented with equal accuracy.

RELATION OF TOPOGRAPHY OF "LIME TOP" TO PENNSYLVANIAN SANDS

Another important effect of the contour of the eroded Lower Mississippian top was its control over the amount, nature, and continuity of the Pennsylvanian sand (partially illustrated in Pl. XIII). The shifting of shorelines (Pl. XXIV) and the variations in depth of water produced locally by the relief of this Lower Mississippian surface as Pennsylvanian waters transgressed it, resulted in discontinuity of Pennsylvanian sands. The relief was too marked to permit continuous deposition of the Pennsylvanian sands that are wide-spread and prolific in the area immediately south.

"TRENTON" STRUCTURE

The black contours of Plate XXVI represent the top of the "Trenton" in the Parker pool, as determined from the well records. The "Trenton" closure practically conforms to that of the Mississippian bedding (that is, about 300 feet, or from 1,575 feet to about 1,870 feet below sea-level), though the Mississippian crest appears to be about a quarter of a mile east of the "Trenton" crest. The "Trenton" has shown oil through a vertical range in elevation of its top of about 85 feet or from 1,575 to about 1,660 feet below sea-level. It is doubtful if the lower 30 to 35 feet of this range will ever produce commercial amounts of oil, but the upper 35 to 40 feet is believed to carry oil in sufficient quantities to make wells possible at the present time in most places. To date the highest "Trenton" well structurally in Parker Township (Associated Producers' Spellbring, NE. ¼ NE. ¼ sec. 7, T. 11 N., R. 14 W.; detailed log No. 107I) is not the best well. The results of drilling on the Parker Township dome to date indicate that the "Trenton" will give some oil through nearly 100 feet range structurally, but that it will not give commercial wells at this time throughout that range under present costs and prices. At present the structural range within which wells can be considered commercial is about 50 feet. The producing wells have little water, and those lower on structure have the larger amounts. In general the farther a test lies down structure, the farther in the "Trenton" must the hole go before finding oil, and the closer the oil lies to water. For example, the highest, structurally, of the wells so far drilled go through the Kimmswick into the Plattin before striking any considerable quantity of water, whereas the edge wells show considerable water in the Kimmswick itself, though its amount after its first appearance increases very gradually.

Drilling and Operation

DRILLING CONDITIONS

SHALLOW WELLS

The length of drive pipe used in the Westfield pool varies from 25 to 150 feet, the average being approximately 50 feet. The drive pipe is commonly set within a day to a day and a half of the time a well is begun. The 6¼-inch pipe, the only string in the wells, is invariably set on top of the Lower Mississippian lime unless the "gas sand" contains enough oil to make a well alone or in conjunction with pay in the lime below, in which case the string is set on top of the "gas sand." The waters to be shut off are chiefly those associated with coals and thin sand streaks; though their amount is small, they must be cased off because the formations cave in open hole in the presence of even a little water. When the "gas sand" and lime both produce in the same well a liner is used to prevent caves. The average time for finishing a 375- to 400-foot well is from four to five days.

In general "lime" wells in the Westfield pool give much poorer shows in "drilling in" than do Pennsylvanian wells of similar size. Many wells that show only a few quarts of free oil, after shooting make as good wells as others whose natural production is sufficient without a shot. Some wells encounter crevices and make much better than average showings, but the oil is sometimes followed up within a very short time by considerable quantities of salt water.

DEEP WELLS

The deep wells in the Westfield pool encounter salt water in the Lower Mississippian lime, in the basal part of the Mississippian, and at the top and in the upper portion of the Devonian-Silurian limestones, all of which must be cased off before drilling into the "Trenton." In addition, the Carper horizon of the Martinsville pool, though not yet found productive in the Parker area must be protected.

Table 16 summarizes the "Trenton" drilling data. The holes either (1) start with 12½-inch drive pipe, land the 10-inch pipe on top of the Lower Mississippian lime (about 300 feet), seat the 8¼-inch below the Lower Mississippian salt water (from 600 to 700 feet), and the 6⅝-inch on top of the basal shaly limestone of the Silurian (from 1,700 to 1,800 feet); or (2) start with 10-inch drive pipe, carry the 8¼-inch through to 600 or 700 feet, mud it off to protect the producing horizon from water from overlying horizons, and then seat the 6⅝-inch at about 1,700 feet. The basal 300 feet of the Silurian carries no water and the shaly and impure limestone beds permit good shut-offs. (See Chapter V.) The mudding in of the 8¼-inch string saves a 300-foot string of 10-inch pipe and thereby reduces the cost of the wells. As the cuttings do not supply an adequate amount of mud of the most desirable quality the use of mud from other sources would be an improvement. However, the use of additional settling pits has brought about a distinct improvement in the mud fluid used in the Westfield pool. The last 600 feet of hole above the top of the "Trenton" carries no water. One well was drilled in 35 days, but two months might be considered good average time to drill and shoot a "Trenton" well. The show of oil in a "Trenton" well, although distinctly noticeable, is small, as would be expected in view of the comparative tightness of the "sand." After drilling in, the wells rarely fill as much as 300 or 400 feet (6-inch hole)

after standing a day or two. After shooting, the wells fill up and within a day or longer will flow varying amounts by heads. Regardless of their size, these wells will flow in time, and some old wells will flow their approximate production if allowed to stand a sufficient length of time. On the pump the wells seem to drop in two or three months to a small part of the first few days' rate of production. But from that time on the production falls off per year less than one-fifth of the three months' figure and the wells are exceptionally long-lived.

The porosity of the "Trenton" varies markedly in short distances, and the productive thickness is so great that even slight variations in the amount of porosity from place to place will have considerable effect on the size of the wells.

SHOT

For "gas sand" wells in the Westfield pool, the size of shot ranges from ½ to 5½ quarts of nitroglycerine per foot. Partial data indicate an average of 2.8 quarts per foot and an average total shot of 102 quarts.

The shot for "lime" wells ranges from ½ to 10 quarts of nitroglycerine to the foot, depending on variations in the "pay," size of hole, etc. The partial data available indicate an average of three quarts to the foot and an average total shot of 99 quarts.

When the pool was first developed practically all the lime from where it first showed oil to the bottom of the hole was shot with as much nitroglycerine as could be placed in that portion of the hole. Later only those parts thought to contain the pay were shot. Some of the pay streaks in the Mississippian lime gave natural production. At the present time some pays in the lower part of the Lower Mississippian lime are not being shot as the shot is of questionable benefit, considering its cost, when all the wells are on suction.

The "Trenton" has been shot with from four to five quarts per foot throughout the entire thickness showing the oil, making in some instances a total shot of about 500 quarts. But the results from shots half that amount per foot have been equally good in other instances. The most efficient shot has not been definitely established. The shot "makes the well," about seven or eight times as much oil being pumped from the well at the end of two or three months as the well would make naturally on drilling in.

PUMPING

The shallow (lime and "gas sand") wells are pumped with pull rods and jack from central powers. The shallowness of the wells permits a great number to be pumped from one power.

The deep ("Trenton") wells are pumped from the central power by the use of over-sized jacks (fig. 10). The "Trenton" oil deposits considerable paraffin (see Table 3, sample 2), and the sucker rods "wax up." When the "Trenton" wells were first pumped, this "waxing up" resulted in many delays, as it necessitated the pulling of a 2,400-foot tubing string and rods every few weeks. Later it was discovered that 10 to 15 barrels of the shallow (Lower Mississippian lime) oil poured into these wells at intervals of about two weeks cut out the wax and eliminated the necessity of pulling jobs from that cause.

The lease powers are all operated by gas engines using gas obtained by the suction on the producing wells.

CORROSION

Both the water and the gas produced with the oil in the Westfield pool have marked corrosive properties. Analyses of some of the waters are given in Table 14. In most instances comparatively large quantities of water must be handled with the oil.

The casing corrodes rather actively both from the inside and outside. It is thought that the outside corrosion is caused by water draining down the outside from leaky stuffing boxes, but it may also be aggravated by sulphides from the coal-bearing horizons above the casing seat. Although the casing corrosion is marked (figs. 7 and 8), it is not as serious as the corrosion of tubing and gathering lines. The tubing, especially in the zone where the operating conditions are such as to expose it to a varying head of water and oil, does not

Fig. 10. View of an "oversize" jack, the type used for pumping "Trenton" wells.

last on the average over two years. Corrosion takes place both from the outside and inside, but the portion of the tubing above the fluid level of the hole does not have the outside corrosion to hasten its destruction. The gathering lines suffer the most marked corrosion, in some instances lasting only three to six months. The high chloride content of the water, the sulphur of the gas, and the intermittent filling and emptying of the gathering lines no doubt all accentuate this corrosion. No corrosion takes place on the outside of the gathering lines.

Corrosion troubles are not evenly distributed, that is, on some leases the effects of corrosion are more marked than on others. On the whole the corrosion of the casing, especially near the casing seat, and of the well tubing and gathering lines, is probably sufficient to cause the premature abandonment of many of these shallow wells on account of the high operating and maintenance

cost. The Ohio Oil Company has experimented with every metallic pipe on the market to obviate the rapid corrosion of the gathering lines. Lead-lined pipe, the latest experiment, is very expensive and has not withstood corrosion successfully as pitting sets in very quickly. Wood-fibre pipe, galvanized pipe, copperized pipe, and other metallic combinations show no improvement over the ordinary tubing or lead lines. However, cast-iron pipe seems to be distinctly better and is being installed on many leases. This pipe is fastened by flange connections with gaskets, and can be used only for gathering lines. It would seem that a solution of the corrosion problem in this pool and elsewhere in Illinois would be the application to the pipe of an inexpensive non-metallic coating. The quantities of water that must be handled in producing the oil are so great as to make it impossible to hope to treat the water. The importance of economically combating the corrosion on the small wells now producing cannot be over-emphasized. R. Van A. Mills of the United States Bureau of Mines gathered some data on corrosion in this pool which are incorporated in a report[2] of that Bureau.

FACTORS OFFSETTING DECLINE

The normal decline of wells in the Westfield pool has been offset to some extent by deepening to lower pay streaks and by the use of the vacuum. Of these two factors, the deepening had the more marked effect. The use of compressed gas is another possible factor which in the future may also tend to offset the normal decline. Each of these factors is briefly commented on below.

DEEPENING

In the central part of the pool, a deepening of 75 to 125 feet where the wells at first were finished in the upper 100 feet of the Lower Mississippian lime has been found beneficial. (See the Tables of Well Data.) But considerable deepening on edge farms and near the border of the limestone production has failed. Usually the immediate "edge production" is from the "gas sand" (Pl. XXVI). Except for possible production from pays below the "lime" it appears that although considerable deepening of "lime" wells remains to be done, the greater part of the benefit obtainable by deepening has already been realized.

A striking example of the benefit of deepening is that of a farm whose production had dropped to 80 barrels a month in 1921 and was raised during that year to 800 barrels a month by the deepening of some holes to the lower pay streaks in the Lower Mississippian lime.

VACUUM

In the Westfield pool the gas pump or vacuum was first installed in 1913. Since that time the whole pool has been put on suction. Though of undoubted benefit, the suction has been a much less important factor in raising or keeping up lease production than has deepening to lower pays.

COMPRESSED GAS

As yet it has not been demonstrated that the introduction of compressed gas into the "gas sand" will be profitable.

[2]Mills, R. Van A., Protection of oil and gas field equipment against corrosion: U. S. Bur. Mines Bull. 233, 1925.

One lease producing oil from the "gas sand" had a compressing plant installed in 1921. But the results, even if available, would not be of much value in judging the practicability of the process, for the wells were initially very small.

One compressing installation that pumped the gas from the Lower Mississippian lime back into the lime lasted only three months, due to the ruinous effect of the gas on the compressor. However, this experience does not prove the scheme permanently infeasible, for once the use of compressed gas has passed through the experimental stage, it may become practicable to wash this gas free of its corrosive elements before compressing.

Gas

The amount of gas produced in the Westfield pool cannot be stated for there is no way of isolating the pool figures from the totals for the whole field, which are themselves indefinite.

Gas was often encountered in the "gas sand," which lies about 60 to 100 feet above the top of the Lower Mississippian lime. Commonly it occurred in association with oil in that sand, but on the higher parts of the Parker dome—where the sand is very poorly developed—without oil and in comparatively small quantities. The only locality where the "gas sand" produced gas alone in considerable quantities lies northeast of the main oil-producing pool, in secs. 22 and 27, Westfield Township.

In a great many of the Lower Mississippian lime wells gas was associated with the oil. The gas wells were not large, rarely if ever having an initial production of as much as 2,000,000 cubic feet. The gas came from the approximate horizon of the "gas sand" (horizon C) where the sand is locally developed on lower structure than the main oil-producing pool. All the gas wells, approximately 13 in number, are now abandoned. All the gas produced at this time occurs in close association with the oil. As a result of the use of vacuum the total amount of gas produced at present is considerable, and much in excess of that needed to run the powers.

Natural-gas Gasoline Plants

One casinghead gasoline plant, that of the American Oil Development Company, is operated in the Westfield pool. It is a compression plant, and employs a gas washer between the suction line and the compressors. As noted in Chapter V, the gas is so high in deleterious sulphur compounds that it has generally been considered impracticable to install casinghead plants up to this time and a great amount of gasoline-bearing gas has been and is being burned by lease flares.

SIGGINS OR UNION TOWNSHIP POOL[3]

Introduction

The Siggins or Union Township pool lies chiefly in Union Township, Cumberland County. Plates I and XXI show its position and extent, and Table 2 states its productive area; the number, depth, spacing, age, average initial and daily production, and average pay thickness of its wells; the number of

[3]Includes Vevay Park production, secs. 24 and 25, T. 10 N., R. 10 E., and sec. 30, T. 10 N., R. 11 E.

abandonments to date; and the estimated total production of the pool and recovery per acre to date. Table 3 gives analyses of the oil. As the structure maps, Plates XXII (B) and XXVII, show, the Siggins pool is located on a decided dome, but the exact direction and relief of its axis in pre-Pennsylvanian formations is not yet known. The southwest flank of the dome is illustrated in cross-section in Plate XV. In the so-called "Vevay Park pool," which lies less than half a mile south of the main Siggins pool in sec. 25, T. 10 N., R. 10 E., the Pennsylvanian strata are domed (Pl. XXVII), but whether the pre-Pennsylvanian formations have like structure is a question. Plates XXII (B) and XXVII also show the well locations in the Siggins pool. Plate VI is a generalized east-west cross section showing the structural relations of the Siggins pool (logs 2 and 3) to the Illinois basin and to the Casey pool (logs 4 and 5).

In 1920 approximately 775 wells were producing oil in the Siggins pool. Using the lease as a unit, the average wells on different leases ranged in production from about a quarter of a barrel to about three barrels per day, but most of the wells produced around one barrel a day. Figures obtained for about 65 per cent of the wells showed an average of about 1.4 barrels per day per well, as stated in Table 2. The maximum recovery per acre in the pool is at least twice the recovery average of 3,030 barrels, stated in Table 2, if not more.

Sands

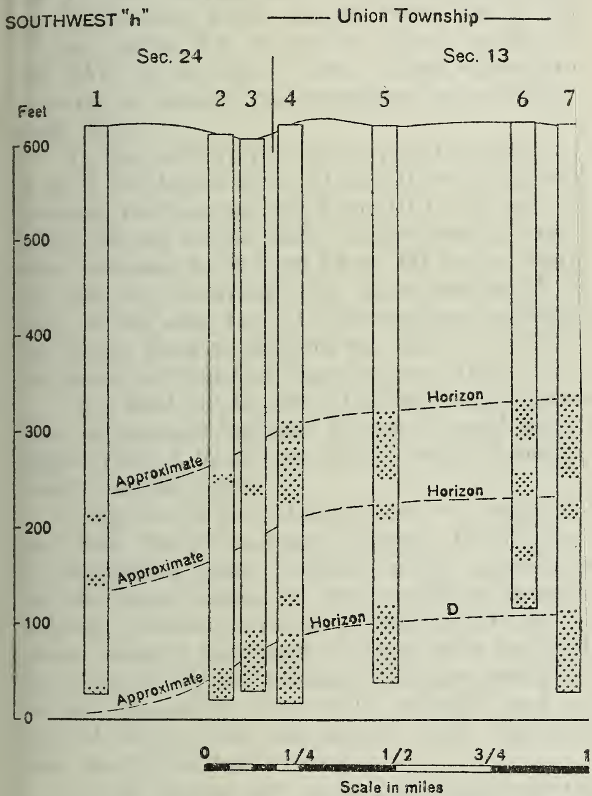
All sands that have produced oil in the Siggins pool to date are of Pennsylvanian age. The Pennsylvanian section is about 250 feet thick. Its sands vary widely from place to place in number, thickness, porosity, and stratigraphic position. The pays occur in multiple streaks varying from one to six, or even more, at any one location, and at least three or four on the average. The richest pays are rarely very thick. Sands in the McLeansboro formation (the "upper Siggins sands"), their tops at approximate horizons A, B, and C, and intermediate, were most prolific, but sands of the Carbondale formation (the "lower Siggins"), their tops at horizons D or E approximately, also produced considerable oil. (See Plate XXIII for the stratigraphic positions of these sand horizons.)

McLEANSBORO ("UPPER SIGGINS" SANDS)

The McLeansboro, which varies from shaly sandstone and sandstone to sandy shale and shale with subordinate amounts of coal and limestone in different parts of the Siggins pool, carries production in pays lying at widely varying levels in its basal 250 feet. In the northern, central, and eastern parts of the main pool, sand is most prominently developed. The McLeansboro sands are made up of well-rounded, well-sorted sand grains, with considerable range in the size of grains and wide variations in the thickness of individual beds.

In this sand zone the number of breaks and their thickness and position are extremely variable. For example, a considerable thickness of sand in one location may be represented in another locality by one, two, or three thinner sands with breaks between; and even where sand is continuous, its nature is extremely variable. Consequently the individual pays are not consistent, the "best pays" following the most favorable sand conditions, and varying in different localities from the top of the zone to the bottom.

The highest of the McLeansboro sands (top at approximate horizon A of Plate XXIII; contoured in Plates XXII (B) and XXVII) is well developed over most of the pool, being at least 65 feet thick on the average; but toward



Detailed cross-section (h-i, Plate XXI), showing the s
the southwest flank of the Siggins dome. The stratigraphi
matically on Plate XXIII.

the southern part, the extreme western edge, and near Vevay Park (sec. 25, T. 10 N., R. 10 E.) it thins and ends rather abruptly. (See cross section, Plate XV.) For example, logs of wells in T. 10 N., R. 10 E., that have gone completely through the sand record the sand thicknesses as follows: in the SW. ¼ sec. 11, the thickness does not average more than about 27 feet; in the SE. ¼ sec. 14 (within which quarter rather abrupt change takes place), it averages 45 feet; in the NE. ¼ sec. 23, 6 feet; in the NE. ¼ sec. 24, 18 feet; and in the NW. ¼ sec. 25, 17 feet. These figures are by no means exact, but they do serve to indicate the abruptness with which the upper sand passes into shale, etc.

In the northern part of the pool the sands, whose tops approximate horizons A to B, are logged from 70 to 100 feet thick and are over 65 feet thick on the average; the best pay lies from 10 to 70 feet (about 30 feet on the average) below the top of the sand. In the central, western, and eastern parts the logs show the sands to be from 15 to 100 feet or nearly 60 feet on the average, with the best pay occurring either at or within 75 feet (on the average about 25 feet) of the sand top. In the extreme southern part of the pool (that is, in the Vevay Park vicinity, in sec. 25, T. 10 N., R. 10 E.), these upper sands are either not noted or logged as very thin.

The sands of the lower 100 feet, approximately, of the McLeansboro (sand tops approximate horizons B and C) tend to be "cleaner." These sands are logged from 5 to 40 feet thick (about 20 feet on the average), and occur at widely varying levels.

Logs record the McLeansboro or "upper Siggins" pays as from 5 to 60 feet thick (on the average 25 feet). Within the thickness logged as pay there is undoubtedly great variation in the porosity and productivity of the sand, but the exact thicknesses that contribute important amounts of oil cannot be isolated. Extreme variations in the porosity and character of the pay sand, with abrupt changes from sand to sandy shale and shale, are encountered. In drilling, parts of the pay horizons show apparently as much shale as sand, possibly in part because the shale drills "muddy" and is therefore unduly conspicuous in drill cuttings, but also because much shale is present interbedded intimately with the thin oil-bearing sands.

In the eastern part of the pool, as may be noted from the Tables of Well Data, the sand zone from horizon A to B encounters salt water, but probably not in great amounts, immediately under the pay. Toward the central part the salt water occurs but rarely, undoubtedly because of the marked discontinuity of the individual sand streaks in this zone, any one of which cannot be followed consistently over the pool.

CARBONDALE ("LOWER SIGGINS" SANDS)

The Carbondale ("lower Siggins") sands (sand tops, approximate horizons D and E) are more widespread than the McLeansboro ("upper Siggins") sands but not as prolific. They are logged from 5 to 100 feet thick, the average being approximately 60 feet. The top of the pay lies at or within 25 feet (average approximately 15 feet) of the top of the sand. The "lower Siggins" pays averaged 19 feet in thickness. Many logs note thin "stray" sands in various parts of the Carbondale section, especially to the south and at the extreme western edge of the pool. On the whole, although the Carbondale is by no means a single uniform sheet sand, its sands are cleaner, more persistent, less variable, and more widespread than those of the McLeansboro.

Salt water is more widespread in the "lower Siggins" sand than in the more prolific "upper Siggins" sands. Wells in this zone show water at considerably higher elevations in the eastern than in the western part of the pool. On the eastern side salt water in large quantities is usually found about 70 feet above sea-level; and on the western side from 10 to 25 feet above sea-level and rarely 50 feet above. On the whole salt water stands nearly 50 feet higher on the eastern side than on the western. Probably this is in part due to sand differences, as certain irregularities which are shown on the records indicate an increased tendency toward the development of thinner sand streaks toward the west. The sand body below production may be continuous across the pool.

DEVONIAN

A Devonian sand has produced gas in two wells in the Siggins pool (No. 30 in the NE. 1/4 sec. 13 (detailed log No. 112), and No. 5 in the SE. 1/4 sec. 13, T. 10 N., R. 10 E.). Two other wells (No. 14 in SW. 1/4 sec. 12 and No. 37 in SE. 1/4 sec. 13, T. 10 N., R. 10 E.) were dry holes in the Devonian. In figure 11, the four holes and the elevations of the Devonian top are mapped. The pay is porous partly dolomitized and partly siliceous limestone, lying at or near the eroded top of the Devonian. Here as elsewhere in the Clark County field, this horizon has shown oil, but has not as yet given commercial oil production. The Devonian limestone lies immediately below the Sweetland Creek (Lower Mississippian) shale and is probably of Onondaga age, but possibly younger.

Structure

"UPPER SIGGINS" SAND STRUCTURE

Contours on the actual top of the first sand recorded, if drawn, would in extreme cases vary from horizon A to horizon D, and would give results comparable to those illustrated by the green contours of Plate XXVIII for the "Casey sand." Such a map would be very confusing and of only partial and subordinate importance in considering commercial oil production, because it would not represent the bedding structure. Instead, therefore, contours were drawn on horizon A (top of upper or first Siggins sand) (Plate XXVII, red contours) over the whole Siggins pool, adjustments being made wherever necessary to bring the sand tops that did not lie at horizon A into agreement with it. As the contours on the lowest Siggins sand (Pl. XXVII, black contours) show that horizon to be practically conformable with horizon A over large parts of the pool, it seemed justifiable to contour horizon A over the whole pool, thereby bringing out the structural relations between the main pool and the isolated Vevay Park production to the south. Of course sand is not present at horizon A everywhere in the pool, but the Tables of Well Data are so arranged as to show conveniently the localities where sands in the upper part of the section have been found thin, or wanting.

The extreme range in elevation of the top of the sand zone from horizons A to B, but not including B, where productive, is 200 feet vertically (from 360 to 160 feet above sea-level). This is found between the central part of the pool and its eastern limits. Elsewhere the range is commonly somewhat less, or about 170 feet (from 350 to 180 feet above sea-level). The steeper dipping western flank of the dome "cuts out" production at a higher elevation than the

flatter northern or eastern slopes. This range applies to the structural bedding range of the zone, not to the individual pays. From the character of the sand disposition and the location of pays, it is not considered possible for a continuous connected pay to exist throughout this whole range.

The part of the rock section from horizon B to D approximately, including B but not D, shows a vertical range in the limits of production of from 350 to 180 feet above sea-level (on horizon A) or 170 feet.

"LOWER SIGGINS" SAND STRUCTURE

The "lower Siggins" sand, approximate horizon D, the lowest producing horizon to date, is contoured in black over the whole pool on Plate XXVII. Sand at this horizon is perhaps more consistently present over the whole pool than individual sand developments in the upper pay zones. It is the main horizon of the Vevay Park district and is well prospected over the southern and western parts of the main pool, though only partially prospected in the central and eastern parts. Plate XXVII shows in black the wells known to penetrate this horizon. The contours for horizon A, in red, show its relation to horizon D, contoured in black. It should be noted that the contours for horizon D in the central and eastern parts are only approximate, due to the lack of data, but as this horizon elsewhere shows conformity with horizon A they may be accepted as correct in the main features. On the whole, the top is fairly consistent in its development, but some variation above and below approximate horizon D undoubtedly has resulted in contours that vary slightly but negligibly from true bedding.

The contours on both horizons A and D show a distinct doming of the Pennsylvanian bedding; the amount of closure is not definitely known, owing to lack of data, but is approximately 190 feet. The extreme range (horizon A) is from 360 to 170 feet above sea-level. The isolated Vevay Park dome has a closure of about 40 feet.

The "lower Siggins" sands (top, approximate horizon D) are productive of oil through an extreme vertical variation in top elevation of 110 feet (from 140 to 30 feet above sea-level, see Plate XXVII). The common range is approximately 80 feet (from 120 feet to 40 feet above sea-level). In the main pool, the horizon produced gas through an elevation range of about 40 feet (from 140 to 100 feet above sea-level). The outlying Vevay Park pool has oil and gas production through a range of about 40 feet (from sea-level to 40 feet above sea-level). This horizon has been an important producing horizon to date only on the western side and south end of the pool.

Drilling and Operation

DRILLING CONDITIONS

SHALLOW WELLS

As most of the water encountered in the Pennsylvanian before reaching the upper producing zone in the Siggins pool occurs in the glacial drift, there is rarely enough water to drill with after the drive pipe (8-inch) is set. A few shallow sands carry fresh water, and some water is encountered closely related to the coals. As the landing of the drive pipe takes about a day and as the average drilling rate is about 120 feet per 24-hour day, the drilling of a well may commonly be completed from three to five days after rigging up. As the

average cleaning-out time for one sand is about two days, and as two to three sands are commonly shot, four to five days is an average for cleaning-out time. The upper sands drill very "muddy." The sand itself drills easily. The oil-producing sands appear brown (the "brown sugar sand" of the driller). The sand in general is very "broken."

In "drilling in" the shows in these Pennsylvanian sands are big compared with shows typical of the field as a whole, but are relatively small considering the resulting production. Only in the most prolific, central portion of the pool is it usual for a 6-inch hole to fill completely with free oil after "drilling in." The sands are in all cases shot.

DEEP WELLS

In the deeper drilling, to the Devonian, the holes are started with 16-inch drive pipe; the 12-inch is carried to about 300 feet; the 10-inch is landed on top of the Lower Mississippian lime at about 690 feet; the 8-inch is carried to about 1,480 feet to shut off the Lower Mississipian lime water; and the 6-inch is set on top of the pay. This arrangement uses one string of casing that is not entirely necessary. The holes could be started with 12½ instead of 16-inch drive pipe, and the 6-inch (with a packer to protect shallow production) carried as a single long string to the top of any gas or oil pay in the Devonian; or the 10-inch could be carried through the shallow pay zones and set above the basal salt water, or could be landed on the top of the Lower Mississippian lime with a packer above the basal salt water to protect the shallow sands.

SHOT

Shooting improves the flow of oil from the McLeansboro sands to a very marked extent.

The shot for the "upper Siggins" (McLeansboro) sands varies from .7 to 7 quarts of nitroglycerine to the foot, averaging about three quarts. The average size of shot is about 81 quarts.

The shot for the "lower Siggins" sands varies from 1.7 to 6.5 quarts of nitroglycerine per foot, averaging about three quarts, and the average shot is about 59 quarts.

These shot averages indicate that the average thickness of sand showing any free oil is about 60 feet, but it must be remembered that in most instances considerable thicknesses of sand are shot which actually have little or no oil but lie between oil-bearing streaks.

When less than 30 feet intervenes between two pays, both are shot together, an anchor containing sticks of dynamite being used between the shots. Perforated liners are introduced where more than one pay is shot. When the pays lie 30 feet or more apart they are shot separately, the lower sand being bridged and the upper sand shot first.

WATER TROUBLES

In the Siggins pool water troubles are not serious in general. Locally where salt water must be handled in considerable quantity, corrosion is very noticeable, but most parts of the pool are relatively free from this difficulty.

In the "lower Siggins" sand (approximate top, horizon D or E) large quantities of salt water closely underlie the pay. The "cementing off" of this water in wells drilled "too deep" has been found beneficial. In most instances

the McDonald method,[4] in which cement is introduced through the tubing, has proved satisfactory. The cement plug is brought up to a break, if a break is noted in drilling, and a stone is placed on top of the cement plug to save the tubing should the cement not set before the tubing is introduced. Details of cementing are given in Bulletin 40[5] and will not be repeated here. On the whole, however, bottom-water trouble is not prominent in the Siggins pool.

FACTORS OFFSETTING DECLINE

The normal decline in the Siggins pool has been offset principally by the development of lower pay streaks in the sand zone, but also partly by the use of vacuum. Considerable opportunity for deepening apparently remains. The use of compressed gas is a third possible factor in offsetting decline. Each of these factors will be commented upon briefly below.

DEEPENING

Plate XXVII shows the wells of the Siggins pool that are known to have reached the lowest Pennsylvanian sand. The considerable number of wells that do not go below the upper first or second pays will be found listed and grouped conveniently in the Tables of Well Data. As salt water is not encountered until the lower sand is reached, many of these wells may be benefited by deepening.

VACUUM

The vacuum was first installed in the Siggins pool in 1919, and practically all the pool is on suction at this time. The average age of the wells, before suction was installed, was about 11 years. An example of the effects of suction is partially illustrated in Table 15.

COMPRESSED GAS

No installations for the introduction of compressed gas or air into the oil sands have been made as yet in the main Siggins pool. It is understood that compressed gas will shortly be installed on some Vevay Park leases.

Gas

Definite data as to the gas production of the Siggins pool are not obtainable, but it is known that the total quantity was not great. Most of the gas was closely associated with the oil, either in local sands in the upper part of the sand zone or in sands intimately interbedded with the oil-producing sands. The lower sands in parts of secs. 24 and 25, T. 10 N., R. 10 E., and sec. 30, T. 10 N., R. 11 E., gave chiefly gas, as noted in the Tables of Well Data. The reduction of the gas supply has been less proportionately than the reduction of "rock pressure." The installation of the vacuum caused an increase, temporarily at least, in the gas production. The amount of gas per well is small—probably not in excess of 1,000 or 1,500 cubic feet per well per day on the average. Where casinghead gasoline plants have been installed the gas is used on lease powers after its gasoline has been removed. Where no such plants are in use, the gas is used directly to run lease powers. In parts of the field there is a

[4] Tough, Fred B., et al, Experiments in water control in the Flat Rock pool, Crawford County: Illinois State Geol. Survey, Bull. 40, p. 140, 1919.
[5] Tough, et al, op. cit.

scarcity of gas for power purposes at this time. Well No. 30, NE. 1/4 sec. 13, and well No. 5, SE. 1/4 sec. 13, T. 10 N., R. 10 E., found gas in the Devonian. Additional drilling to this horizon is discussed in Chapter VII, Future Prospecting.

Natural-gas Gasoline Plants

Four casinghead gasoline plants are operated in the Siggins pool, three by the Ohio Oil Company and one by Bell Brothers.

YORK POOL

Introduction

The York pool is located in Crooked Creek Township, Cumberland County. Plates I and XXI show its position and extent. Table 2 states its productive area; the number, depth, spacing, age, average initial and daily production, and average pay thickness of its wells; the number of abandonments to date; and the estimated total production of the pool and recovery per acre to date. The structure map, Plate XXVII, shows the Pennsylvanian strata to be domed in the York pool, but whether the pre-Pennsylvanian formations have like structure is a question. Plate XXII (B) shows all the wells and dry holes in the pool.

The relatively high percentage of dry holes (53½ per cent) as compared with other pools in the Clark County field does not reflect actual pool conditions, but is due instead to the many dry holes drilled close to the north end of the York pool in an attempt to connect it with the Union Township production less than 3 miles away.

Sands

The producing sand of the York pool is in the Carbondale formation of the Pennsylvanian. Its top lies approximately at horizon D of Plate XXIII. The McLeansboro sands that produce in the Siggins pool are not developed or represented to any extent in the York pool. The average thickness of pay logged was about 17½ feet.

Small quantities of salt water are associated with the oil production. (See Tables of Well Data.)

Structure

The sand of the York pool was contoured at horizon D. The structure map, Plate XXVII, shows that the production is apparently on flattening associated with very slight doming. Production is found through a 60-foot (maximum) range in elevation of the sand top.

Factors Offsetting Decline

Of the factors offsetting normal decline in other pools of the Clark County field, only vacuum has been tried in the York pool. The vacuum was first installed in July, 1919. Deepening of the wells within the Pennsylvanian is not expected to increase production materially. Perhaps Chester pays may be encountered below the Pennsylvanian.

Gas

In a considerable number of holes gas occurs in sand overlying and closely associated with the oil pay—in some instances in considerable quantities. The largest recorded gas wells had an initial production of 2,000,000 cubic feet. Most of the gas came from "stray" sands above the oil pay.

A deep hole on the Mullen farm in the NW. ¼ sec. 7, T. 9 N., R. 14 W. (detailed log No. 123)[6] failed to find gas in the Devonian.

CASEY POOLS

Introduction

The Casey Township production, comprising the North Casey pool and the main Casey pool, lies largely in Casey Township.[7] Plates I and XXI show its position and extent. Table 2 states its productive area; the number, depth, spacing, age, average initial and present daily production, and average pay thickness of its wells; the number of abandonments to date; and the estimated production of the pool and recovery per acre to date. Analyses of three oil samples from the Casey pools are included in Table 3.

The structure maps (Pls. XXII (B) and XXVIII) show the Casey pools to be associated with slight domings or flattenings of the Pennsylvanian strata. Whether the pre-Pennsylvanian formations have like structure is not known. Plates VI, XVI, and XVII are cross sections showing some of the structural relations of the Casey Township production.

The large percentage of dry holes (25 per cent) drilled in the Casey pools reflects the existence of considerable areas of spotted and very light production which were in part tested or drilled up as completely as wholly productive leases.

The available statistics of production during 1920 indicated an average per well, taking leases as units, of about .7 barrels per day per well, as stated in Table 2. The production ranged from about 1/10 of a barrel to about 1½ barrels per day per average lease well, but most of the wells were producing around half a barrel per day.

The maximum recovery per acre for the Casey pools is doubtless greatly in excess of the estimated average of about 1,125 barrels as stated in Table 2.

Sands

Pennsylvanian, (McLeansboro, Carbondale, and locally possibly Pottsville sands), Upper Mississippian (Chester), and Lower Mississippian (St. Louis?), all produce some oil in the Casey pools. Of these the Casey sand of Carbondale age is the most prolific and the "gas sands" of McLeansboro age next in importance. Chester and Lower Mississippian production is rare.

PENNSYLVANIAN

MCLEANSBORO ("GAS SANDS" AND "STRAYS")

The McLeansboro sands are important only in the North Casey pool. Sands whose tops lie approximately at horizons B and C and intermediate between A and B, ("gas sands" and "strays") are productive of oil or gas. Horizon C is

[6]A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

[7]The production in secs. 35 and 36, Casey Township, is grouped geologically (Tables of Well Data) with the north Johnson Township production, but in the matter of statistics, the political division is used. The production in secs. 7 and 18, Casey Township, is grouped both geologically and statistically with the Siggins pool. The remainder of the Casey Township production comprises the "Casey pools."

contoured in green for the North Casey Pool on Plate XXII (B) and in red on Plate XXVIII, and the disposition of sand at or close to this horizon is partially illustrated by Plates XVI and XXVIII.

The "lower gas sand" (top, horizon C) is prominently developed over the whole North Casey pool, where it is logged as from 10 to 50 feet thick, averaging about 30 feet in sec. 33, T. 11 N., R. 14 W. (Parker Township), and about 25 feet in secs. 2, 3, 4, and 5, T. 10 N., R. 14 W. (Casey Township). It averages about 22 feet in thickness in sec. 13, T. 10 N., R. 14 W., in the main Casey pool, but is not important commercially there. The "lower gas sand" is the most important pay horizon of the North Casey pool.

The "upper gas sand" (top, horizon B) is present in sec. 33, T. 11 N., R. 14 W. (Parker Township), and secs. 2, 3, 4, and 5, T. 10 N., R. 14 W. (Casey Township). Its average logged thickness is about 40 feet. Part or all of the "lower gas sand" (top, horizon C) is sometimes included with it, and is so listed occasionally in the Tables of Well Data. This horizon is not contoured for the Casey pools, but its disposition and development are partially illustrated by Plate XVI. Southward in Casey Township the McLeansboro sands thin rather abruptly and become irregular and of no commercial importance, though in the main Casey pool, they are occasionally noted as are somewhat higher sands which are prominently developed in the Siggins pool. These sands exist also in the Martinsville pool, and there as in the Casey pool, locally show sand and considerable gas; but they are unimportant commercially and are erratic as to the porosity and continuity of the sand.

In the North Casey pool the average thickness of McLeansboro pays logged is 21 feet.

CARBONDALE (CASEY SAND)

The Carbondale (Casey) sands are the most prolific in the Casey pools. In most places the top of the productive sand lies approximately at horizon E, but in some places at horizon D. Horizon E is contoured in green (Plate XXII (B) from sec. 10 south to sec. 35, Casey Township (T. 10 N., R. 14 W.). The sands with tops approximately at horizons D and E approach each other and then combine as the eroded surface of the Lower Mississipian rises northward along the strike of the anticline.

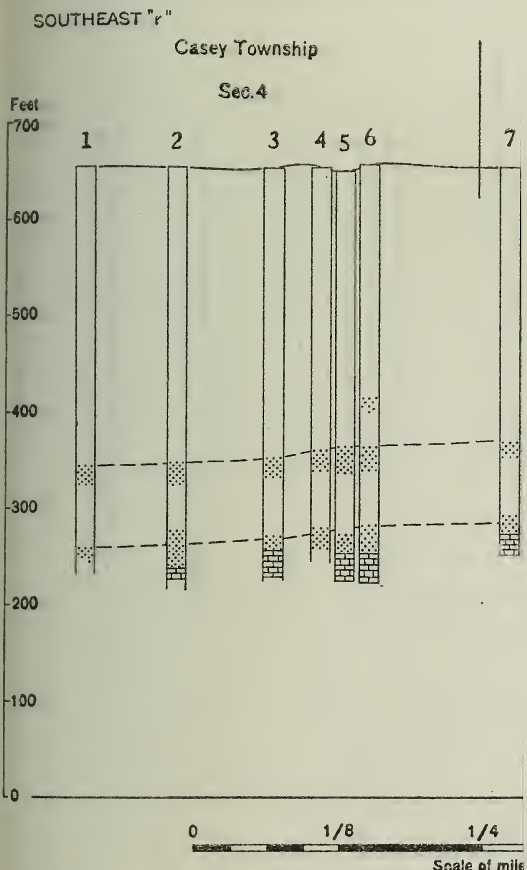
The Casey sand is present but not commercially important in the North Casey pool. In sec. 33, T. 11 N., R. 14 W. (Parker Township), the Casey sand top corresponds with horizon D, and the average thickness logged is from 10 to 30 feet, averaging about 25 feet. In secs. 1, 2, and 3, T. 10 N., R. 14 W. (Casey Township), the sand top lies at or a little below horizon D and the average thickness logged varies from 10 to 60 feet averaging 35 feet. In secs. 4 and 5, Casey Township, the sand top lies somewhat above sand horizon E and the thicknesses logged vary from 10 to 25 feet, and average 20 feet. In secs. 13, 14, and 15, Casey Township, the Casey sand is represented by two beds, rather consistently separated, which, according to the logs, have an average combined thickness of about 30 feet. In secs. 22, 23, 24, 25, and 26, Casey Township, the Casey sand is in some places represented by as many as three sands, their total logged thickness averaging about 35 feet, with the individual sands varying from 10 feet up. The average thickness of pay logged for the Casey sand is 24 feet. This thickness is made up of streaks that vary widely in porosity, productivity and thickness.

MISSISSIPPIAN

CHESTER (UPPER MISSISSIPPIAN)

Chester remnants, their thickness varying but little, give production locally in Casey Township (...

LLINOIS STATE GEOLOGICAL SURVEY



Detailed cross-section (r-s, Plate XXI), showing
...orthwest-southeast line across the North Casey pool.
...atically on Plate XXIII. Note the lesser thickness
...wer (Nos. 2, 3, 5, and 6).

... of a closure. (1) Northward the Lower Mississippian lime top lies progressively higher and terminates this sand and its associated strata; and (2) in this part of the rock section there is a progressive decrease of sand and increase of shale northward.

contoured in green for the North Casey Pool on Plate XXII (B) and in red on Plate XXVIII, and the disposition of sand at or close to this horizon is partially illustrated by Plates XVI and XXVIII.

age combined thickness of ...

Township, the Casey sand is in some places represented by as many as three sands, their total logged thickness averaging about 35 feet, with the individual sands varying from 10 feet up. The average thickness of pay logged for the Casey sand is 24 feet. This thickness is made up of streaks that vary widely in porosity, productivity and thickness.

MISSISSIPPIAN

CHESTER (UPPER MISSISSIPPIAN)

Chester remnants, their thickness varying but little, give production locally in Casey Township (see Table of Well Data and detailed logs 113A and 113B). In the North Casey pool and in most of secs. 10, 11, 13, 14, and 24, T. 10 N., R. 14 W., in the main Casey pool no Chester remains. Elsewhere in the latter pool it is generally present, becoming thicker southward and westward. Production to date from the Chester in Clark County is relatively rare.

LOWER MISSISSIPPIAN ("LIME" PAY)

The St. Louis limestone is the uppermost Lower Mississipian formation throughout the Casey pools except possibly locally where a little Ste. Genevieve may cap it. The hardness and fine grain of the St. Louis made it comparatively resistant to weathering, and so it developed less porosity while subjected to pre-Pennsylvanian erosion than did the Spergen limestone which was uppermost in most parts of the Westfield pool. Doubtless it is for this reason that although the St. Louis gives a little production in the North Casey pool, and in that part of the main pool where it is not capped by any of the Chester remnants, the "lime" production has been relatively unimportant.

The Spergen limestone, present beneath the St. Louis everywhere in the area of the Casey pools, was protected from the pre-Pennsylvanian erosion by the St. Louis and therefore, unlike the Spergen of the Westfield pool, is not porous; and further the Spergen was not truncated anywhere close to the Casey pools, so that it was not a path for the movement of underground waters, by which porosity might have been developed during pre-Pennsylvanian time.

STRUCTURE

NORTH CASEY POOL

On Plate XXII (B) the principal sand of the North Casey pool, the "lower gas sand" (approximate top, horizon C) is contoured in green and all the wells of the pool are shown. On Plate XXVIII horizon C is contoured in red, but only those wells are shown that gave data usable directly without adjustment. In addition on Plate XXVIII the eroded top of the Lower Mississippian (horizon L of Plate XXIII) is contoured in black, and the Casey sand (horizons D and E, and intermediate) in green. The contours on the Casey sand are submitted to illustrate the high degree to which the sand contours may vary from true bedding structure; and, studied in conjunction with the black contours on the same map and with Plate XVI, they also show the relation of the unconformable Lower Mississippian top to sand disposition and deposition.

Horizon C seemed to conform better than other horizons with the bedding, and may be considered as reflecting the McLeansboro bedding structure approximately. The contours indicate that the production is associated with a flattened anticlinal nose. No closure is shown, although the profile of Pennsylvanian bedding, Plate VIII, suggests the probability of a 60-foot closure to the north. But even in the absence of bedding closure, two conditions would give the equivalent of a closure: (1) Northward the Lower Mississippian lime top lies progressively higher and terminates this sand and its associated strata; and (2) in this part of the rock section there is a progressive decrease of sand and increase of shale northward.

The behavior of the sand with respect to the "lime high" of the North Casey pool is in part illustrated on Plates XVI and XXVIII. It will be seen to be somewhat similar to that of the sand at horizon B over the Parker dome (Pls. XIII and XXVI) where, although the Pennsylvanian bedding undoubtedly has a closure, the termination or thinning of the sand toward the "lime high" at the central part of the dome is the determining factor in the location of production.

Within the area of production in the North Casey pool, the maximum rate of dip in Pennsylvanian bedding is about 80 feet to the mile. The sand produces through a vertical range of about 40 feet in the elevation of its top.

Because the top of the first sand of the Casey zone lies in some places at approximately horizon D, and in others at horizon E or an intermediate position, contours on the top of the first sand give results that not only deviate from true bedding but also from contours on the tops of sands that "clear" the Lower Mississippian lime top. (Compare red and green contours on Plate XXVIII and see section, Plate XVI.) The contours on Plate XXVIII and the section on Plate XVI show a bedding error 15 to 20 feet in excess of the true bedding.

The unconformable top of the Lower Mississippian (horizon L of Plate XXIII) is contoured in black on Plate XXVIII. Nosing similar to that shown by the Pennsylvanian contours is indicated, but the rate of dip is greater—about 150 feet to the mile for the Lower Mississippian, as against a maximum of about 80 feet to the mile for the Pennsylvanian. And because the Lower Mississippian thickens southward, the true bedding dip is considerably in excess of that of the unconformable top. The stratigraphic relationship of horizon L of the Casey pools to horizon L of the Westfield or Parker pool cannot be determined satisfactorily because of lack of data, but it is clear that the progressive thickening of the Lower Mississippian southward causes horizon L to lie stratigraphically higher and higher, and therefore to deviate progressively farther and farther from the true bedding in that direction.

(MAIN) CASEY POOL

Sand-top horizon E corresponds well with the top of the Casey sand in the main Casey pool and has been contoured over the entire pool. In secs. 14 and 15, T. 10 N., R. 14 W. (Casey Township), the contours on horizon E (in green, Plate XXII (B)) show a doming with a closure of about 60 feet. The dome is approximately flat on top and the steepest dip is on the west, where within the area of production it has a rate of 200 feet to the mile for a short distance, and about 175 feet to the mile on the average. The dip to the east is much gentler. No other appreciable closures are found in this pool.

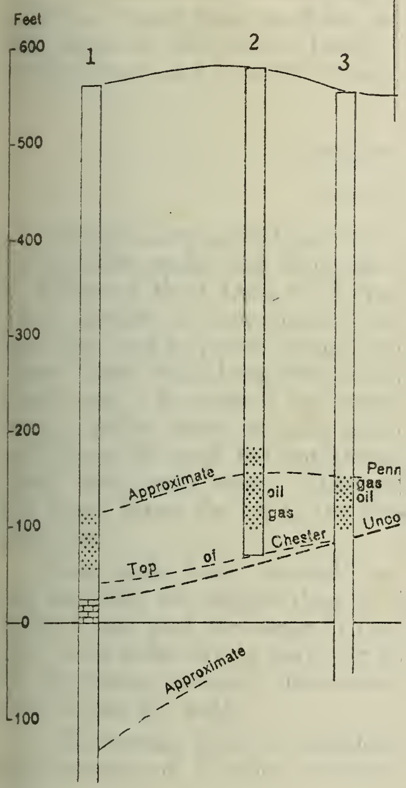
The maximum productive range in elevation for sand-top horizon E is about 60 feet but the maximum productive range in the elevation of actual sand tops is about 100 feet. This occurs on the steep western slope where sands with tops at horizons E, F, or intermediate, vary in elevation from 200 to 100 feet above sea-level.

Plate XVII, a section across the south part of the Casey pool, illustrates an important feature of Pennsylvanian production in the pool. The unconformable Mississippian top (whether Chester or Lower Mississippian) rises eastward, so that the lower part of the Casey sand was not deposited in the eastern part of the pool. This relationship is similar to that in the North Casey pool, where the northward rise of the unconformable Mississippian top caused absence of the Casey sand.

WEST "k"

Casey T

SEC. 26



1 V
2 V
3 V
4 V
5 D
6 V
7 V
8 D
9 V

(N
abov
numl
and

Detailed cross-section (k-l, Plate
eroded top of the Lower Mississippia

It should be noted that although
surface, sand is commonly found either

Cas
to l
(Pl
edl
hig
of

of
duc

app
con
bed
Mi
and
on

XX
by
150
80
thi
unc
poc
fac
of
hig
fro

the
15,
gre
dor
wit
dis
is

abc
san
wit
fee

an
abl
so
of
the
the

It is interesting to note that here as elsewhere in the Clark County field, wherever a sand comes in direct contact with the eroded, weathered, and therefore more or less porous Lower Mississippian limestone, the amount of oil retained even on a favorable structure is rarely of commercial importance.

Drilling and Operation

DRILLING CONDITIONS

In the Casey pools from 50 to 80 feet of either 8¼ or 10-inch drive pipe is commonly needed and about one day is required for setting it. (Details given in Tables of Well Data.) Towards the North Fork, as the drift is thicker, greater lengths of drive pipe are required. The wells are commonly about 455 feet deep, and 6¼-inch casing is usually landed on top of the pay sand. A "flinty" lime shell (lying close to the No. 6 coal horizon) occurs above the main Casey sand. As most of the water is shut off by the drive pipe, the 6¼-inch string is pulled when the sand is shot. Some water is commonly associated with coals above the sand, but not always enough to drill with. McLeansboro sands locally carry some water. The prospects for benefiting wells drilled into the salt water below the oil in the main Casey pool by cementing are not at all promising.

Some wells have "natural" production, but on the whole the show of oil and the wells are smaller than in either the Siggins or Johnson pools. In the North Casey pool the range in the amount of free oil shown on drilling in is wide, some wells having only very slight creamy shows, others flowing naturally. On the whole, however, the shows of free oil are comparatively small, and the shot "makes the well."

The average time for completing a well, which includes drilling, shooting, and cleaning out, is about one week, working "tower."

SHOT

In the North Casey pool the McLeansboro sands are shot with from one-half to five quarts of nitroglycerine, on the average 2½ quarts per foot. The average shot is about 50 quarts.

In the main Casey pool, the Carbondale (Casey) sand is shot with from 1¾ to 6½ quarts, on the average 2¾ quarts per foot. The average shot is about 90 quarts. When two sands are shot, liners are usually employed.

FACTORS OFFSETTING DECLINE

Of the three factors tending to offset decline, vacuum is by far the most important in the Casey pools. The use of compressed gas and the possibilities for deepening are also commented upon briefly below.

VACUUM

Vacuum was first introduced in the Casey pools in 1916, with the results shown in Table 15. All of the main pool is now on vacuum, but not the greater part of the North Casey pool (specifically sec. 33, Parker Township, and secs. 3, 4, and 5, Casey Township). The wells were about nine years old on the average before vacuum was first installed.

COMPRESSED GAS

In 1921 experiments on the use of compressed gas were started in the Casey pools. Increased production was obtained, but figures concerning the commercial application of this process are not available at this time.

DEEPENING

But little deepening that promises to benefit production noticeably remains to be done in the Pennsylvanian zone, as multiple pays like those so prominent in the Pennsylvanian of the Siggins pool are not common in the sands of the Casey pools.

Gas

It is not possible to isolate the exact quantity of gas produced from the Casey pools. Only eight wells are termed gas wells, most of the gas being associated with the oil. In the North Casey pool considerable quantities of gas are found in the upper part of the sand zone, or the upper part of the oil-producing sand. To date, with the installation of vacuum, the supply of gas has been sufficient to run lease powers.

Natural-gas Gasoline Plants

There are two casinghead gasoline plants in the Casey pools.

MARTINSVILLE POOL

Introduction

The Martinsville pool lies chiefly[8] in Martinsville Township, Clark County. Plates I and XXI show its position and extent. Table 2 states its productive area; the number, depth, spacing, age, average initial and daily production, and average pay thickness of its wells; the number of abandonments to date; and the estimated pool production and recovery per acre to date. Plates XXII (B) and XXIX show the locations of its wells and also its structure. That the pool is located on a dome is clear, but the shallow production does not occur over the whole dome and sufficient data are not available to show the exact direction of axis and extent and relief of structure in the pre-Pennsylvanian formations.

Analyses of oil from the "Trenton" and Carper sands are included in Table 3; no analyses for the younger sands are available.

It is estimated that during 1920 the wells of the Martinsville pool averaged around .6 of a barrel per day, the lease well average ranging from about one fourth of a barrel to a maximum of about two barrels per day.

Sands

Pennsylvanian sands, both McLeansboro and Carbondale, produce some oi and gas. The St. Louis limestone and the Kinderhook[9] of the Lower Mississippian and the Maquoketa and "Trenton" (Kimmswick) of the Ordovician als

---

8Sec. 6, T. 9 N., R. 13 W., Orange Township, is grouped geologically as part of th Martinsville pool.

9The Kinderhook (Carper) and the "Trenton" production were discovered as a resul of the publication of structural conditions by the Illinois State Geological Survey in it Press Bulletin of July 10, 1920, Mylius, L. A., Oil and gas prospecting outside southeaster Illinois.

produce oil. Of these, the St. Louis limestone has been the most important to date, with the Pennsylvanian sands next in importance. At the present time only two Carper sand wells and one "Trenton" well are completed. The Carper sand promises to be the more important of the two.

PENNSYLVANIAN

MCLEANSBORO ("250-FOOT SAND")

Sands of McLeansboro age whose tops lie approximately at horizon A or intermediate between A and B ("250-foot sand," etc.) occur generally over the Martinsville pool. Although the logs used for Plate XVII do not show these sands present over the crest of the fold, they are logged in other nearby wells (see Tables of Well Data) and all holes found considerable sandy shale in that part of the rock section. The sand is apparently better developed south of the crest of the fold, particularly in sec. 30, T. 10 N., R. 13 W. The thickness, as logged, varies up to 75 feet. In secs. 19, 20, 29, and most of 30, T. 10 N., R. 13 W., these sands show only small amounts of oil and considerable water. At the south end of the pool, including sec. 6, T. 9 N., R. 13 W., Orange Township, a McLeansboro sand produced important amounts of gas. The data available are too far from complete to permit contouring or comprehensive study of this sand.

CARBONDALE (CASEY SAND)

The Casey sand (top, approximately horizon E or D and intermediate) is stratigraphically the lowest Pennsylvanian sand of the Martinsville pool. Its top is reached at depths of 415 to 500 feet in different parts of the pool. The sand is irregularly developed. Over most of the present producing area, it lies directly on the eroded surface of the Lower Mississippian limestone (St. Louis). Its thickness varies from 10 to about 55 feet. The maximum thickness is found in secs. 19 and 29; there its top lies above horizon D. But where its thickness is at a minimum, its top lies below horizon E, and the strata lying between its top and horizon D are chiefly made up of sandy shale or shaly sandstone, described by the drillers as "broken sand."

The Casey sand shows some oil generally throughout the pool, but only in parts, notably in secs. 19 and 29, T. 10 N., R. 13 W., where it has its maximum thickness, was it ordinarily considered worth shooting and then usually only in conjunction with pay in the immediately underlying Lower Mississippian lime. In these two sections the upper part of the Casey sand yielded considerable gas, and usually only the lower 20 feet gave oil. In other parts of the pool also, the upper part of this sand probably gave some of the gas.

The basal part of the Casey sand carries salt water, negligible amounts in the central part of the pool, but considerable quantities toward the edges of production.

The Casey sand had an average logged pay thickness of about 27 feet.

MISSISSIPPIAN

Oil is produced at two horizons in the Lower Mississippian, the upper being that of the Martinsville sand, and the lower, the Carper sand of the Kinderhook.

LOWER MISSISSIPPIAN ("LIME" OR MARTINSVILLE SAND)

The Martinsville sand (horizon L) is in the St. Louis limestone of the Lower Mississippian. The pay is the somewhat altered slightly and rather irregularly porous upper part of the Lower Mississippian limestone and underlies the Pennsylvanian unconformably.

Owing to the greater resistance of the St. Louis to weathering as compared with the Spergen, the Martinsville (St. Louis) lime pay, like that of the Casey pool, is less porous and less deeply porous than the Westfield (Spergen) lime pay. Though the Spergen everywhere underlies the Martinsville pool, it is everywhere capped by St. Louis both in and near the area of the pool; and as it was thus protected from the action of percolating surface waters during pre-Pennsylvanian time, it lacks sufficient porosity for oil accumulation. Though only the upper 30 feet of this limestone is to be classed as pay, this zone nevertheless has been to date the most important oil-producing horizon of the pool. In some places the top of the pay lies at or very close to the top of the lime, but more commonly from 5 to 10 feet below the top. One well found a pay over 100 feet below the top of the lime, however. The average pay thickness logged was about 20 feet. Salt water is associated with and underlies the oil in the Martinsville sand over the area of production. In the central part of the pool its amount is negligible, but increases toward the edge of production.

UPPER KINDERHOOK (CARPER SAND)

The Carper sand is part of the Upper Kinderhook formation and lies just above the Sweetland Creek (chocolate shale) which is the basal formation of the Lower Mississippian in this region. The first Carper sand well on the John Carper farm in the NE. ¼ sec. 30, T. 10 N., R. 13 W., was shot in June, 1922. The exact thickness of the sand in that well is not known. The initial production after the shot was about 140 barrels. At the end of the first week, the well had dropped to about 25 barrels per day, but was still pumping 20 barrels a day five months later. The second well in the Carper sand, Barr No. 1, NE. ¼, sec. 30, T. 10 N., R. 13 W., was drilled about 65 feet into the sand and finished in sand. Of this thickness 50 feet was shot. The upper 5 to 10 feet showed considerable gas. The amount of free oil shown during "drilling in" was not large. The hole (6-inch) filled only about 150 feet with oil after standing over night. No data are available at present on the production of this second well.

The Carper sand is a fine-grained sandstone with considerable shaly sandstone and a few thin clean shale breaks. It is capped by a varying thickness of shale. Even the pay has the bluish-gray color typical of all the Lower Mississippian formations. The sand grains are rather uniform in size, a condition to which the porosity is due. It is a comparatively soft sand,—a 5-foot screw in a 6-inch hole at 1350 feet drilling up in 20 to 30 minutes,—but appears to be less porous than the average true sands in the Clark County field. The behavior of the first tests indicates that the Carper sand wells will probably be long-lived rather than large.

ORDOVICIAN ("TRENTON" AND "CLINTON" SANDS)

So far only two holes have reached the "Trenton"[11] (Kimmswick) in the general vicinity of the Martinsville pool, one a producing well, the other, dry.

[11]Mylius, L. A., Oil and gas prospecting outside southeastern Illinois: Illinois State Geol. Survey Press Bulletin, July 10, 1920.

The Charles McFarland well in the NE. ¼ NW. ¼, sec. 19, T. 10 N., R. 13 W. (detailed log 119A),[12] reached the top of the "Trenton" at a depth of 2708 feet, the Lowe dry hole in the SE. ¼ NE. ¼, sec 25, T. 10 N., R. 14 W. (detailed log No. 120),[12] at 2709 feet. Both holes are on the west slope of the Martinsville dome. The McFarland well, had good shows of oil in the limestone member of the Maquoketa (the "Clinton"), but the "Trenton" showed more oil on drilling in and the "Clinton" was not shot. The total thickness of Kimmswick (160 feet approximately) was not drilled on the McFarland well. The well was first finished 60 feet below the "Trenton" top, and was later deepened by about 65 feet. The lower half of this pay showed more free oil than the upper. The well was shot in January, 1922, and gave rather typical "Trenton" flush production. It flowed several hundred barrels intermittently before the well was put on the pump, and pumped approximately 125 barrels a day the first two days. It dropped, however, on pumping to about 10 barrels a day within a few months. Tests higher on the structural closure will probably give larger wells. The pay is limestone, apparently more coarsely crystalline and toward the base sandier than the "Trenton" pay of the Parker pool; the show of free oil during "drilling in" was also in excess of that encountered in the Parker pool to date. As these conditions seem to indicate that the "Trenton" in the Martinsville pool is less "tight" than in the Parker pool, the chances for larger wells in the former than in the latter pool seem good, though not so good as to make general drilling to the "Trenton" advisable at this time. The oil in the limestone member of the Maquoketa may be expected to add somewhat to the production and should be handled along with the "Trenton".

Structure

CASEY SAND STRUCTURE

The data available were insufficient to permit contouring of the Casey sand over more than a small part of the Martinsville pool. In the area contoured the sand top approximates horizon D, which is somewhat above the true Casey sand top of Casey Township. Undoubtedly a closure exists at this horizon. Its amount is probably small, judging by the apparent flatness, partially illustrated by Plate XVII. The productive range in the elevation of the sand-top horizon is about 30 feet. The dip varies from almost nothing to 100 feet to the mile on the productive eastern slope. Plates XVII and XXIX show the relation of the Pennsylvanian structure to the eroded top of the Lower Mississippian lime.

LOWER MISSISSIPPIAN LIME STRUCTURE

Plate XXIX shows in black the contours on the unconformable top of the Lower Mississippian limestone (horizon L of Plate XXIII) over that part of the Martinsville pool for which sufficient data were available. The Mississippian bedding conforms locally with the erosional top (see Plate XVII), but the data are insufficient to show the exact areal extent of such conformity.

The closure on horizon L,—that is, the highest part of the erosional surface,—corresponds approximately at least with the structural closure. The Lower Mississippian thickens comparatively abruptly to the west, as shown on Plate XVII and undoubtedly thickens somewhat in all directions from the

[12]A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

central part of the closure, though apparently least northwestward. On account of this thickening the contours on the top of the Lower Mississippian (horizon L) only partially illustrate bedding structure and should be used for structural purposes only where data on the amount of thickening are not available. It would appear at present that the area of thinnest Mississippian, which is also the area within which the eroded Lower Mississippian top and the Mississippian bedding are highest, extends a little east of north through secs. 19, 20, 29, 30, and 31, T. 10 N., R. 13 W. But it remains for future drilling to define the exact limits and character of the Martinsville dome. Thus, the Lower Mississippian top may be used confidently as a general guide to structure in the central part of the dome only, and even there it is probable that the crest of the Lower Mississippian bedding structure may be a little west of the crest of the Lower Mississippian erosional high. The contours of Plate XXIX show a closure of about 20 feet. Just where thickening eastward begins is not known at this time, but if the thickening east and northeast is very abrupt, making the closure on the deeper beds of comparatively small areal extent, the Carper sand production may "cut out" before the edge of the shallow lime production is reached.

Production in the lime at Martinsville is found over a variation in elevation of about 50 feet in its eroded top.

CARPER SAND STRUCTURE

Though data as to the Carper sand are as yet very few, certain facts and relations are already clear:

The nature and geological history of the Upper Kinderhook (pp. 57, 87, and 111) are such as to indicate that the Carper horizon will probably have enough sand to make a well in most parts of the area, providing the necessary structural conditions are present. Thus, whereas production in the Pennsylvanian and the Lower Mississippian lime pays is related as vitally to other conditions as to structure, the Carper production is dependent to a major extent on structure alone. For this reason, correct structural interpretation of the Lower Mississippian bedding is highly important to Carper prospecting. As has been explained above, the map, Plate XXIX, though picturing not Lower Mississippian structure, but the topography of the Lower Mississippian lime top, may to some extent be used as a guide to the structure. At least it will serve to guide the drilling of the first Carper wells, and eventually data from these first and later wells will serve to define the Lower Mississippian structure.

Drilling and Operation

DRILLING CONDITIONS

SHALLOW WELLS

The length of drive pipe (8-inch) varies from about 150 to 200 feet and the well is considered half finished when the drive pipe is landed. It takes from one to two and one-half days (on "tower") to land the drive pipe, the average being about two days. The rate of drilling, after bed rock is reached, averages about 100 feet a day. Most of the wells place the $6\frac{1}{4}$-inch string on the persistent shell, associated with No. 6 coal, that is found at a depth of 360 to 400 feet.

The amounts of oil shown by the shallow pays on drilling in are not great. The Casey sand carries only light pay, as a rule. The Martinsville lime cuttings are brown to creamy colored and medium hard. The lime shows are very light, but even when they are only "rainbows," shooting will often result in wells.

CARPER (1300-FOOT) WELLS

The Carper (1300-foot) wells start with 10-inch drive pipe and land the 8¼-inch string on the top of the Lower Mississippian lime at approximately 500 feet. The 6¼-inch, landed at about 1200 feet, is used to shut off the last water above the pay, which, although not great in amount, is undesirable in open hole on account of the tendency of the shales associated with the pay to cave.

The salt water underlying the lime pay in the central part of the pool in sec. 30, T. 10 N., R. 13 W., is not more than enough to drill with usually, but toward the edges increases in amount. Water in the Lower Mississippian limestone may be encountered at any depths in the first 400 to 500 feet, but the only wide-spread water comes about 400 to 500 feet below the top of the lime. Varying, but relatively small amounts of salt water are found 200 to 250 feet above the chocolate shale.

The Carper sand appears in drill cuttings as a bluish, fine-grained sand with considerable shaly sand. It drills easily (5-foot screw in 20 to 30 minutes), and shows (relative to the size of the wells) only a small amount of free oil. The 6-inch holes fill from 100 to 200 feet over night.

"TRENTON" WELLS

To date 12-inch drive pipe has been used in the "Trenton" wells, though with this size sufficient protection cannot be given to the Carper (1300-foot) pay. With 12-inch drive, the 10-inch is landed in the top of the Lower Mississippian lime at 500 feet, the 8¼-inch is carried to 1300 feet, and the 6¼-inch is landed at about 2300 feet in the shaly, impure limestones of the lower Niagaran. The next wells should start with a larger drive pipe. Table 18 summarizes the "Trenton" drilling data.

Salt water is associated with the Carper sand and is encountered in large amounts in the Devonian 20 to 40 feet below the chocolate shale. Large quantities of water are found 150 to 250 feet below the chocolate shale in sandstone and sandy dolomite, the big "Niagaran" water of the driller. The underlying Silurian limestone does not contribute any troublesome amount of water.

The "Trenton" drill cuttings show creamy, crystalline limestone which drills (depending upon the type of machine, size of hole, etc.) rather slowly, that is, from 1½ hours to 3½ hours per screw, the first figure being rather exceptional. In the McFarland well the upper part of the "Trenton" pay did not show as much free oil as the lower portion. After standing two days the oil had risen about two hundred feet in 6-inch hole.

SHOT

The shot for the Pennsylvanian sands of the Martinsville pool varies from 1½ to 6 quarts—on the average about four quarts nitroglycerine per foot, or about 120 quarts per well.

The Martinsville sand (the Lower Mississippian lime pay) is shot with from three to eight quarts—on the average about five quarts of nitroglycerine per foot, or about 110 quarts per well.

All the sand at the Carper horizon that is considered oil-bearing is shot with from two to three quarts of nitroglycerine to the foot. The shot gives an initial production about ten times as large as the natural production, and at the end of the year about two or three times the initial natural figure. The "Trenton" is usually shot with five quarts to the foot. The most efficient shot has not been determined as yet.

CORROSION

The salt water from the Martinsville lime corrodes lead lines and casing. The corrosion is not as active as at Westfield, and the average life of the gathering lines is probably about five years.

BOTTOM-WATER

In the Martinsville pool, there is slight possibility of benefiting production by cementing to exclude bottom-water.

FACTORS OFFSETTING DECLINE

The decline in production of the shallow Martinsville wells was more marked than in most parts of the field, due in part probably to the type of pay. Most wells dropped to five or ten barrels in a week or two, and to two or three barrels in a few months.

Factors that have offset decline elsewhere (such as deepening to lower pays and the use of vacuum) have not been operative in the Martinsville pool to any considerable extent. The possibilities are discussed briefly below.

DEEPENING

In the shallow sand zones no important benefit can be expected from slight deepening. No doubt some additional production can be obtained by deepening those wells that were finished above the Lower Mississippian lime into the upper 30 feet of the lime. The practicability of deepening is directly related to the price and cost of producing oil. Development of lower pay horizons (Carper and "Trenton") gives the greatest promise.

UNDRILLED ACREAGE

In the Martinsville pool considerable acreage remains that will give light wells in the shallow sands. Increase in the price of oil may make it good business in the future to drill up leases not fully drilled, or to drill untested leases.

VACUUM

The vacuum or "gas pump" has not been installed in the Martinsville pool. One reason is that the main producing sand is an erratic limestone pay. In the Westfield pool the limestone is consistently more porous and the vacuum is therefore of benefit.

Gas

There were 17 gas wells in the Martinsville pool, and as noted, the gas produced in sec. 6, T. 9 N., R. 13 W., Orange Township, where there are 10 wells, should logically be grouped with this pool. The gas wells were located in the SE. ¼ sec. 30 and in sec. 31, T. 10 N., R. 13 W. No exact data as to the amount of gas are obtainable. One well was reported at 20,000,000 cubic feet with a pressure of 70 pounds. The highest pressure noted was 150 pounds.

The gas is chiefly obtained from what is called the 250-foot sand in the Martinsville pool (approximately horizon A or intermediate between A and B). Salt water is encountered in the base of the gas sand and in some instances proved very deleterious.

Natural-gas Gasoline Plants

There are no casinghead gasoline plants in the Martinsville pool. The total gas production of all the wells in the shallow sand is probably insufficient to warrant even a small plant at this time.

JOHNSON AND ORANGE TOWNSHIP POOLS

Introduction

The Johnson and Orange Township pools cover parts or all of secs. 2, 3, 10, 11, 12, 13, 14, 15, 22, 23, 26, 27, 34, 35, Johnson Township (T. 9 N., R. 14 W.) and secs. 6, 7, and 18, Orange Township (T. 9 N., R. 13 W.)[13]

Plates I and XXI show their position and extent. Table 2 states their productive area; the number, depth, spacing, age, average initial and daily production, and average pay thickness of their wells; the number of abandonments to date; and the estimated pool production and recovery per acre to date. Plates XXII (B and C) and XXX show the locations of the wells and the structure. As the contours indicate, there is well-defined doming of the Pennsylvanian strata in the southern part of Johnson Township and but slight warping in the northern part. Doming of the pre-Pennsylvanian strata is suggested more strongly for the southern than for the northern part of the area.

No analyses of oil from the Johnson and Orange pools are available.

The initial production of the wells varied from approximately 5 barrels to 1500 barrels a day, this pool giving the largest wells in the Clark County field. Many wells gave from 200 to 500 barrels initial production, and as Table 2 shows, the average was 84 barrels per well.

By 1920 the average production per lease well varied from one-fourth of a barrel to about five barrels per day, or an average of 1.3 barrels per day per well.

It is estimated that the pool has produced 18,400,000 barrels. Parts of it were the most productive localities in the Clark County field, and the recovery per acre of 4770 barrels, stated in Table 2 is the highest in the Clark County field. The maximum is greatly in excess of this average figure.

Sands

All the sands producing to date in the Johnson and Orange pools are of Pennsylvanian age. McLeansboro sands give stray pay, but are comparatively unimportant. Below the McLeansboro, the following sands are found in various parts of the pool, the horizons given being those of Plate XXIII:

Claypool	Top, Horizon D
Casey	Top, Horizon E
Upper Partlow	Top, Horizon F
Lower Partlow	Top, Horizon H

[13]This is the basis of division in considering statistics, etc., but in the Tables of Well Data the field grouping includes secs. 35 and 36, Casey Township, with secs. 2, 3, 10, 11, 12, and parts of 14 and 15, Johnson Township, in one group, and secs. 7, and 18, Orange Township, parts of 12, 13, 14, and secs. 22, 23, 26, 27, 34, and 35, Johnson Township, in a second group. Section 6, Orange Township, would be grouped geologically with the Martinsville pool, but no data are available.

The Claypool, Casey, and upper Partlow sands are of Carbondale age, and the lower Partlow of "older Pennsylvanian" (possibly Pottsville) age. The most wide-spread production occurs in Claypool sands, but the most prolific wells are in lower Partlow sands.

MCLEANSBORO (KICKAPOO SAND)

The McLeansboro formation includes the Kickapoo sand of sec. 11, T. 9 N., R. 14 W., which is listed, wherever it was logged, in the Tables of Well Data.

CARBONDALE AND "OLDER PENNSYLVANIAN" (CLAYPOOL, CASEY, UPPER AND LOWER PARTLOW SANDS)

In the northern part of the Johnson pool (that is, from secs. 14 and 15, Johnson Township north including secs. 35 and 36, Casey Township) the Claypool sand (top, horizon D) is the most important sand; but in the southern part of the pool, (that is, from secs. 22 and 23 south, and including also secs. 12 and 13, all in Johnson Township), the upper Partlow sand (top, horizon F) is most important. To be more specific the upper sands (Claypool and Casey; tops, horisons D and E, respectively) thin southward from the north end of the pool, disappearing at the south end, while the lower sands (Partlow; tops, horizons F and H) are absent at the north end of the pool and appear and thicken southward to their maximum at the southern end; in other words, from the vicinity of sec. 14 (roughly along the line on Plate XXII (B) that separates the horizon D and horizon F contours) the upper sands become commercially important and thicken northward, the lower sands southward. The following average sand thicknesses for certain sections in the Johnson pool (based on data in the Tables of Well Data) show more specifically the changing thickness and importance of the sands from north to south in the pool.

Section	Sand thickness		
	Claypool and Casey	Upper Partlow	Lower Partlow
	Feet	*Feet*	*Feet*
Casey Township			
35 and 36	65	absent	absent
Johnson Township			
1 and 2	65	absent	absent
11	50	"	"
12	*a*	*a*	"
13	17	25	"
14	30	25	"
15	25	15	"
22	erratic	30	"
23	30	30	"
24	rarely noted	30	"
26	" "	60	25
27	" "	65	30
34	" "	60	25
35	absent	65	30

*a*Combined thickness of Claypool, Casey, and upper Partlow only 15 feet.

Most of the wells in the northern half of the pool find the top of the first pay at horizon D, but in some instances at horizon E or intermediate.

As shown in the Tables of Well Data for both Casey and Johnson townships, sands with tops approximating horizon D are so thick as to extend downward to and below horizon E. From a practical standpoint the Casey and Claypool sands (tops, horizons D and E, respectively) might even be considered as one sand as in many instances they constitute a continuous sand body. However, they are discussed separately to make the behavior of the sands, bedding, etc., clear.

Irregular breaks are very common in the sands with tops at horizon D or E, but their thickness and position are not consistent.

The upper Partlow sand (top, horizon F) logged on the average 50 to 60 feet thick in the southern half of the pool, includes breaks and in some places is two distinct sands. Horizon F lies 100 to 130 feet below horizon D in section 15, T. 9 N., R. 14 W.

Since the lower Partlow sand is "older Pennsylvanian" age, and the upper Partlow, Carbondale, an unconformity is thought to lie between these two sands in secs. 26, 27, 34, and 35, T. 9 N., R. 14 W., where both are present. The dissimilarity of the contours for the two horizons, given in black and red, respectively, on Plate XXX, bear out this idea. Horizon H lies 150 feet below horizon F in sec. 35, T. 9 N., R. 14 W.

The average logged thickness of pay in the Claypool sand (top, horizon D) was about 21 feet. The average for the upper Partlow sand (top, horizon F) was about 23 feet. The average for the lower Partlow sand (top, horizon H) was about 15 feet. It is doubtful if the actual thickness of what could be considered good pay (that is parts that contributed enough oil to help materially in making the well) exceeds 15 feet in any of these sands and this thickness usually occurs in more than one streak.

In general in the north half of Johnson Township all oil-producing sands have some edge water and the thicker sands have water at the base. In the southern half of the township the upper Partlow (top, approximately horizon F) shows some basal water over most of the area, though except near the edge of production not enough to prevent drilling through without extra casing. In sec. 26 and vicinity, the basal part of the lower Partlow (top horizon H) carries greater quantities of water than do the upper Partlow or higher sands. It is noteworthy in this connection that the lower Partlow sand is closely allied with the "big water" sand of the Bellair pool which has never produced oil.

Structure

The Claypool sand (horizon D) is contoured on Plate XXII (B) over secs. 35 and 36, Casey Township, and secs. 1, 2, 3, 10, 11, 14 and 15, Johnson Township. The contours show no pronounced large dome, but rather slight doming, warping, and flattening. The data for secs. 12 and 13, Johnson Township, and secs. 6, 7, and 18, Orange Township, were not sufficient to permit comprehensive contouring. Some of the logs, as noted in the Tables of Well Data, had to be

adjusted to horizon D. An extreme example of sand disappearance or top variation is shown by Plate XVIII. It will be noted that to the west the change comes rather abruptly (at the east line of sec. 3 on Plate XVIII).

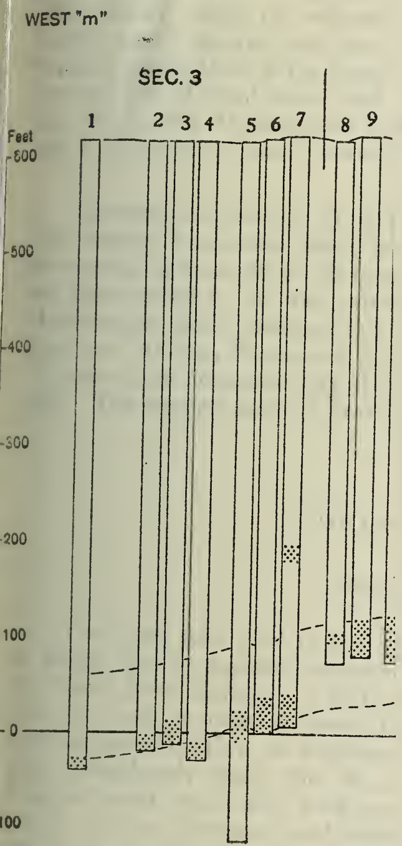
In secs. 12, 13, 22, 23, 24, 26, 27, 34, and 35, Johnson Township, where the Claypool sand (top, horizon D) ceases to be the main top, the upper Partlow sand (top, horizon F) becomes most important, and is contoured over that area. Some of the logs had to be adjusted to horizon F. The variations of the sand top from sand horizon F are both above and below, and in general, as the Tables of Well Data show, the top lies above at the north and below to the south. Horizon F is, however, the only available horizon that will serve to picture the approximate bedding.

The contours on the "older Pennsylvanian" sand horizon (approximate sand top, horizon H) for secs. 26, 27, 34, and 35, Johnson Township, in black on Plate XXX, show the existence of a pronounced dome, called the South Johnson, in those sections. A comparison between the contours of this horizon and those of horizon F, in red on the same plate, shows a disconformity between them; towards the edges of the dome, horizon H dips more steeply than horizon F. The vertical interval between the two horizons varies from 110 to 140 feet. The horizontal displacement suggested by the contours is at least 800 feet.

No very marked doming exists in the north Johnson pool, that is, in the area from secs. 35 and 36, Casey Township, to and including secs. 14 and 15, Johnson Township. There is, however, a distinct flattening north and south (paralleling the high eroded Mississippian top). Some closures of about 20 feet occur, and a 40-foot closure is shown in sec. 11, Johnson Township. This part of the producing area shows very little, if any, reversal of dip to the east. The extreme productive range in the elevation of the prominent sand top is 160 feet (from 200 to 40 feet above sea level), but through this range the pay does not occur in the same part of the section. The usual range is about 100 to 200 feet above sea-level. To the east there is some production associated with the flattening, the productive areas being controlled by sand conditions and therefore rather small and isolated. In the area of production the rate of dip varies from approximately flat to an extreme of 400 feet to the mile on the western slope. In general it appears that the production is due partly to the flattening of the Pennsylvanian bedding, but also to the "cutting out" of the sands northward and eastward or to their non-deposition eastward, giving the equivalent of closure. Locally on this flattening, small domes with slight closures to the east have also controlled production. Rising of the Lower Mississippian top similar to that which causes the "cutting out" of certain sands in this pool, is illustrated by the general north-south section, Plate II; by Plate XVII; and also by the longitudinal section, Plate VIII. The non-deposition of a sand eastward is partially illustrated by Plate XVIII.

The structure of horizon F, Plate XXX, indicates a continuation of the north-south flattening from and including secs. 22, 23, to and including secs. 35 and 36, and also secs. 12 and 13, all in Johnson Township. The closures in this area, controlled at the north usually, do not exceed about 30 feet. In the area of production the western dip is not as steep as it is farther north, but the eastern dip is very marked. The maximum productive range in the

[ILL]INOIS STATE GEOLOGICAL SURVEY



NE. ¼ section 3

1 Well No. 13
2 Well No. 106
3 Well No. 12
4 Well No. 10a
5 Well No. 11
6 Well No. 10
7 Well No. 6

(Note: The well numbers in

Detailed cross-section (m-n, Plate
stratigraphic position of contour horizon

elevation of the sand top is about 80 feet (from 500 to 420 feet above datum or from 100 to 20 feet above sea-level). The usual range is about 60 feet (from 500 to 440 feet above datum). In the area of production the rate of dip varies from practically nothing to about 200 feet to the mile on the west. The smaller range in sand-top elevations of the productive zone here than farther north accords with the tendency of production to occur in the higher horizons rather than in the lower. The southward pitch of the Lower Mississippian top has allowed some sand at approximate horizon F to develop eastward over the Lower Mississippian erosional high in and toward Orange Township. There is, however, some restriction in the sand over the high.

Contours on horizon H, Plate XXX, show a closure of at least 40 feet. The extreme productive range in the elevations of the sand top is 70 feet, and the average is from 40 to 50 feet (15 to 60 feet below sea-level, or 185 to 140 feet above datum). To the north the sand with top H "cuts out" on the Lower Mississippian high, making the bedding closure still more effective in that direction. Within the area of production the rate of dip of approximate horizon H varies from approximately flat to about 350 feet to the mile on the western edge. The steepest pitch of horizon F has a rate of about 200 feet.

Drilling and Operation

DRILLING CONDITIONS

The drive pipe used in the Johnson and Orange pools varies considerably in length due to marked variation in drift thicknesses from place to place in the North Fork Valley. The 6¼-inch pipe is commonly landed on top of the first pay sand, in most instances the Claypool in northern Johnson Township, and the upper Partlow in southern Johnson Township. A persistent lime shell lying immediately above the No. 6 coal horizon and about 25 feet above the Claypool sand top is also used sometimes for a casing point. The first wells drilled in the Claypool sand stopped when the bit encountered white sand, which was usually, though not always, fine-grained. These wells were later deepened through the white sand and pay sand was found below. The wells were originally stopped on the basis of "let well enough alone," the color and other characteristics of the sand suggesting water. The amount of free oil shown by the different pay streaks varies considerably. Wells in Carbondale sands (the Claypool and upper Partlow sands) rarely flow; many fill with oil but others which are commercially important after the shot, have as little as two hundred feet of oil after standing over night (6-inch hole). Wells in the "older Pennsylvanian" (lower Partlow) sand flow in many instances in contrast with most of the wells in the Clark County field.

SHOT

The Claypool sand is shot with from 1 to 7 quarts of nitroglycerine per foot,—about four quarts on the average,—and the average size of the shot is about 110 quarts. The upper Partlow is shot with from 1 to 6½ quarts, an

average of about 4 quarts to the foot, and a total shot average of about 12C quarts. The lower Partlow sand is shot with from 2 to 12 quarts,—on the average 4½ quarts to the foot,—and the average size of shot is about 65 quarts

BOTTOM-WATER

Wells drilled too deep into the lower Partlow sand have needed plug of either cement or lead. to protect the pay from the inflow of salt water lying immediately below the oil.

FACTORS OFFSETTING DECLINE

The principal factors that have offset the normal decline of the Johnsor and Orange pools are deepening of wells and use of vacuum. Compressed gas further deepening and additional wells are future possibilities. Each of thes factors is commented upon briefly in the following paragraphs.

VACUUM

The vacuum or gas pump was first installed in the Johnson pools in 1916 at which time the wells were about nine years old on the average. Practicall the whole pool is on the gas pump at this time. The effects of the vacuur are partially illustrated in Table 15.

DEEPENING

Considerable deepening in the Claypool and upper Partlow sand zones ha been completed already, but some still remains to be done. Taking the poc as a whole, deepening has been more beneficial than in the Casey pool, but le so than in the Siggins. Deepening to lower sand zones is discussed unde Future Prospecting, Chapter VII.

EXTRA LOCATIONS

The drilling of additional shallow sand wells must await either highe prices for oil, or decreased production costs resulting from improved metho of oil recovery, etc. The sand zones contain enough "stray pays" in places t suggest possible benefit.

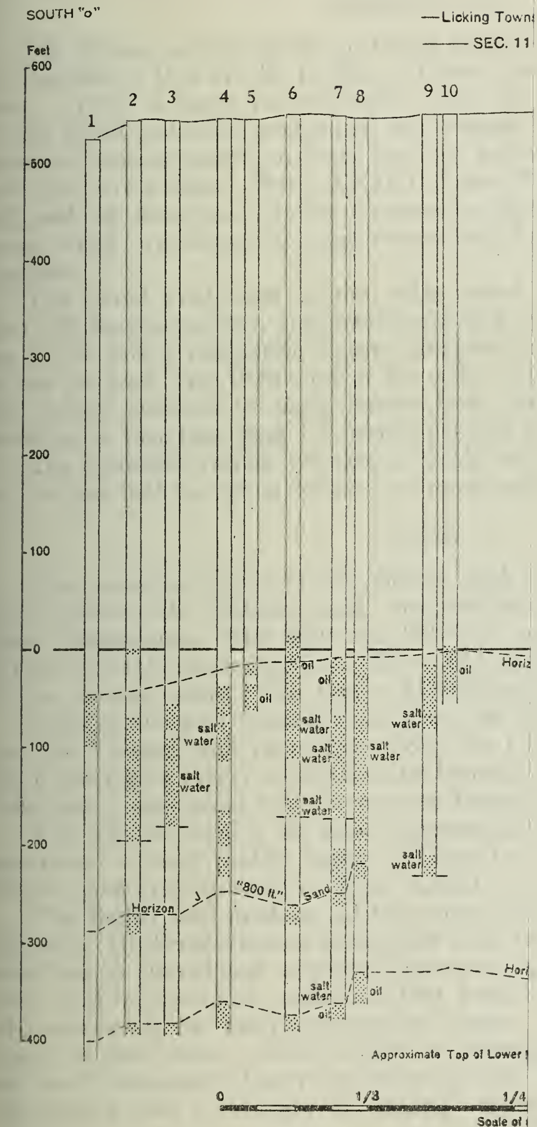
COMPRESSED GAS

The first complete installation of compressed gas in the Johnson pool w in 1921, though a few partial experiments had been made earlier. The wel responded with considerable increase in production, but no exact data as to tl commercial success of the process are available at this time.

Gas

The amount of gas associated with oil production is less in the Johnson ar Orange pools than in the other pools of the Clark County field. Twenty-eig wells gave only or chiefly gas. The gas wells in sec. 6, Orange Townshi are known to have been among the biggest in the field though no exact figur are available. The pressure rarely exceeded 150 pounds. Where the gas c- curred alone it came usually in sand with tops at horizons A to C and inte- mediate. But most of the gas occurs in close association with the oil in t main oil-bearing horizons. Due to the adoption of suction, considerable g is still being contributed by the oil wells.

Illinois State Geological Survey



SE. ¼ section 11

1 Well No. 40
2 Well No. 39
3 Well No. 38
4 Well No. 24
5 Well No. 25
6 Well No. 13
7 Well No. 14
8 Well No. 16
9 Well No. 5
10 Well No. 4

(Note: The well numbers in the above list on Plates XXII and XXXI.)

Detailed cross-section (o-p, Plate XXI), sh mately north-south line through sec. 11, Licking contour horizons G, J, and K, is shown diagra

BELLAIR POOL

Introduction

The Bellair pool lies in the northwest corner of Crawford County, in Licking Township (T. 8 N., R. 14 W.). Plates I and XXI show its position and extent. Table 2 states its productive area: the number, depth, spacing, age, average initial and daily production, and average pay thickness of its wells; the number of abandonments to date; and the estimated pool production and recovery per acre to date. Plates XXII (C) and XXXI show the location of the wells and the structure. As the contours on these maps indicate, the Pennsylvanian strata are domed to some extent and doming of the Mississippian is suggested.

The initial production of the wells varied from very small amounts to about 700 barrels per day, and many wells had over 100 barrels initial production. The initial production figures obtained gave an average of 59 barrels per day per well. By 1920 most of the wells were making over a barrel a day. The average obtained by using figures from about 25 per cent of the wells producing at that time gave 1.7 barrels per day per average lease well.

The estimated average recovery of 3,950 barrels per acre to date is doubtless less than half the actual recovery on some leases.

Sands

The producing sands of the Bellair pool are in the Carbondale of the Pennsylvanian (the 500-foot sand; top, horizon G), and in the Chester or Upper Mississippian (the 800- and 900-foot sands; tops, horizons J and K of Plate XXIII, respectively).[14] Plate XIX is a cross section illustrating the relation of these sands. The Lower Mississippian to date has rarely produced.

Parts of the pool produce only from the Pennsylvanian sands, parts only from the Chester, and parts from both the Chester and the Pennsylvanian. The Chester gave bigger wells than the Pennsylvanian, but the area of Chester production is only about half the area of Pennsylvanian production.

The 500-foot sand is the most widespread, but the 900-foot, next in areal importance, is more prolific locally. These two horizons and (partially) the 800-foot sand are contoured on Plate XXXI.

The Bellair pool produces oil from more varied sands than does the Westfield pool. Its Pennsylvanian production is in true sandstones, and its Chester production in altered and unaltered limestones, in unaltered discontinuous sandstones, and in truncated sandstones that have been "sealed" at or near their old outcrops on the pre-Pennsylvanian erosion surface by deposition of limy cement in their pores. Only locally do Pennsylvanian shales directly overlie and "seal" truncated Chester pay horizons; but the nature of the Chester pays themselves is such as to assist in "sealing" them at the old erosion surface.

PENNSYLVANIAN (500-FOOT SAND)

In the Pennsylvanian of the Bellair pool, the sand tops lie at erratic and varying levels to a greater extent than in the pools farther north. Sand tops approximating horizon G (the 500-foot sand) were sufficiently prevalent, however, to permit contouring of that horizon (see red contours, Plate XXXI). Incomplete data show an average logged pay thickness of about 30 feet.

[14]It should be noted that the sand called the 800-foot at the north end of the Bellair pool is the equivalent of the 900-foot sand of the main pool.

CHESTER

THE 800-FOOT SAND

As illustrated in part by Plate XIX, that part of the rock section in which the 800-foot sand occurs, has been removed by truncation in the north-central and north parts of the pool, so that the northernmost production from the 800-foot sand is in the SW. ¼ sec. 12, T. 8 N., R. 14 W. The most important production from the 800-foot sand is in the neighborhood of sec. 14, T. 8 N., R. 14 W., where that sand is logged from 5 to 40 feet thick averaging 25 to 30 feet, and sometimes occurs as two pays. In the NW. ¼ and the NE. ¼ sec. 13, same township, it is also important, its logged thickness averaging about 20 and 15 feet respectively in the two quarter-sections.

The limits of production in the 800-foot sand correspond roughly with the limits of the area over which the green contours are drawn on Plate XXXI.

The average pay thickness logged was about 18 feet.

THE 900-FOOT SAND

In the 900-foot sand zone, two pays occur in parts of the pool and only one elsewhere, their position and thickness being rather variable. The thickness of the zone is about 50 feet or less on the average. Where two pays are present they commonly, but not invariably, lie in the upper and lower parts of the zone respectively, and where but one is present, in the lower part. The average pay thickness logged was about 18 feet.

The shifting of the pay from one part of the zone to the other occurs erratically and is not easily detected. Another element of confusion is that sands occur both above and below these two 900-foot pays.

The usual white, hard, crystalline lime shell of the most consistent 900-foot sand is considered to be about 115 feet below the level of the top of the most consistent 800-foot sand.

Structure

As shown by Plates VIII, XIX, XXII (C), and XXXI, the area of the Bellair pool as a whole is structurally a dome. At the north end, present data do not indicate closure in excess of 30 feet "controlled," but the relief in other directions is considerably greater. Over this large dome smaller domes with closures of 20 to 30 feet occur. The rate of dip varies over the dome from practically nothing to 200 feet to the mile.

500-FOOT SAND STRUCTURE

The contours in green on Plates XXII (C) and in red on XXXI, represent the structure of the 500- foot (horizon G) sand. As shown on Plate XXXI, the actual top of the 500-foot sand varies considerably from the true bedding,—in fact, more so than do Pennsylvanian sands elsewhere in the Clark County field. As a result the adjustments necessary in contouring this horizon were more numerous than elsewhere in the area as may be noted in the Tables of Well Data. The contours on horizon G show that the Pennsylvanian strata lie rather flat within the productive area of the 500-foot sand. The 500-foot sand zone is productive through a maximum range of elevation on horizon G of from 60 to 70 feet, the common range being about 50 feet.

800-FOOT SAND STRUCTURE

Contours on the top of the 800-foot sand, horizon J, are shown in green on Plate XXXI. In the area contoured, only small actual closure is shown, about 20 feet "controlled" at the north. The relief in other directions is more marked. The dips are sharper than those of the Pennsylvanian as represented by horizon G. The tendency toward discontinuance of specific porous beds and local vertical change in position of the most porous bed makes the contours somewhat less reliable than contours on more persistent beds. But in general, in spite of this possibility of error, the main features are doubtless shown correctly. As noted in the Tables of Well Data sands occur above and below the 800-foot sand top, so that in some instances the establishing of the contour horizon was only a matter of personal judgment. Though it is thought that the maximum error could not be over 30 feet, still with only a 40 to 80-foot range of production, it is obvious that such an error cannot be considered negligible.

Over part of the area contoured the 800-foot sand is productive through an extreme range of about 80 feet in elevation of its main top, but as a rule the range does not exceed 40 to 50 feet. In the area of production the rate of dip varies from practically nothing to 300 to 350 feet per mile.

900-FOOT SAND STRUCTURE

The work of contouring the main 900-foot sand top (horizon K, contoured in black, Plate XXXI) was very difficult on account of the variability of the sand and pay occurrence, and the lack of adequate data. In consequence the contours should be considered as having locally a possible maximum error of about 30 feet. A likely place for such error to occur is along the junction of the areas where the 900-foot sand loses its two pays and passes into one pay. For example in the NW. ¼ sec. 1, and NE. ¼ sec. 2, T. 8 N., R. 14 W., two pays, their tops vertically 30 to 35 feet apart, are prominently developed in the 900-foot zone, but in the SW. ¼ sec. 1, and the SE. ¼ and SW. ¼ sec. 2, there is rarely more than one pay; in contouring, the lower pay may have been incorrectly considered the main 900-foot sand.

On account of the possibility of error in contouring the SW. ¼ sec. 1, and SE. ¼ sec. 2, T. 8 N., R. 14 W., the structural relation of the southern to the northern part of the pool as shown is not entirely dependable. Bedding behavior in the high part of the dome, as shown, may also be questioned chiefly on account of the lack of logs. At the southeast end of the pool the intervals vary greatly, as noted in the Tables of Well Data, between the 800- and 900-foot sands.

The structure as shown by the contours is essentially a nose on which slight doming occurs. North in Johnson Township there is a possibility of a reversal, though no direct data are available; but even without reversal, the "cutting out" of the Chester to the north may give the equivalent of a closure. The central dome on this flat nose shows a closure of about 20 feet. In the area of production the rate of dip varies from almost nothing to approximately 200 to 250 feet to the mile. On the western slope of the central dome the 900-foot sand production appears to have a maximum range of 100 feet in the elevation of the main sand top, but it is possible that the pay has migrated in the section and that the bedding range is actually less than shown as suggested by the "coming in" of red rock over the pay to the west. The southern

part of the pool shows a second dome with about 20-foot closure. The exactnes of this closure may be questioned, due to the lack of usable data. The maximun productive range in sand-top elevation is from 60 to 70 feet. Locally the range is considerably less.

It should be noted that the Chester sands dip somewhat more steeply ir the area of production than the Pennsylvanian, and that locally the somewhat steeper dips in the Chester sands "cut out" production with less range in the ele vations of the sand top than where the dips are flatter. Because of its gentle dips both locally and over the whole pool, the Pennsylvanian has had an are of production considerably in excess of the Chester.

Plate XIX illustrates in section the relation of the different sands. Com parison of the Pennsylvanian and Chester contours presented on Plate XXX indicates rather close agreement of the Pennsylvanian and Chester in the struc turally high parts of the dome, and increasing disagreement in "off-structure" direction.

From a practical standpoint the importance of determining Chester struc ture as distinct from the Pennsylvanian is demonstrated by the fact that th flatter Pennsylvanian carries production over areas where more acutely folde Chester cannot be expected to produce.

The main horizons of the 800- and 900-foot sands are conformable.

Drilling and Operation

DRILLING CONDITIONS

In the Bellair pool the drive pipe (usually 10-inch) varies in depth, a may be seen in the Tables of Well Data. The 8-inch pipe is commonly lande on the top of the 500-foot sand. In the holes going to the Chester pays, th 8-inch string is usually run almost to the top of the 700-foot water sand an the 6¼-inch is set on top of the pay. Usually there is only enough water t drill with between the drive pipe and the 700-foot sand. The drilling fro the 700-foot water sand to a suitable casing point for the 6¼-inch string difficult, due to the caving nature of the Chester shales. The landing of th drive pipe usually takes about 24 hours, and on the average the 900-foot san wells are drilled in about two weeks. It takes about a week and a half to clea out and put a well on the lease power.

The shows of oil in the 500-foot sand at Bellair are not unlike the amoun shown by the Pennsylvanian sands over the rest of the Clark County fiel The shows from the 900-foot sand are greater, and many wells give natur production.

SHOT

The 500-foot sand is shot with from 2½ to 7 quarts, about 3.6 quar of nitroglycerine per foot on the average. The average shot is about 12 quarts.

The 800- and 900-foot sands are shot with from one to six quarts, or abou three quarts of nitroglycerine per foot on the average. The average shot about 55 quarts.

CORROSION

Salt water handled in the production of oil corrodes the lead lines to bu a slight extent except on the western side of the pool, where considerable quan tities of salt water are handled with the 900-foot sand production, and whe some of the lead lines have lasted only eight months.

"FLOATING SAND" AND "CUT OIL"

In the 500-foot sand the cutting of the cups by "floating sand" is troublesome. The oil from the 500-foot sand (sample No. 14, Table 3) cuts easily.

FACTORS OFFSETTING DECLINE

The normal decline of the Bellair pool has been offset by the use of vacuum. Other means of offsetting the decline,—deepening of wells, drilling of extra locations, and the use of compressed gas,—are also commented upon below:

VACUUM

The vacuum or gas pump was first installed in the Bellair pool in 1919, at which time the average age of the wells was about ten years. At present most parts of the pool, or at least the line wells of all leases, are on the vacuum.

DEEPENING

The deepening of some Chester wells in the Bellair pool is expected to give beneficial results, as may be noted from study of the Tables of Well Data. But the Pennsylvanian sand zone does not offer many possibilities of beneficial deepening.

EXTRA LOCATIONS

Good opportunities are still offered by normal inside locations for drilling to the 900-foot sand in the Bellair pool. It is doubtful if extra locations to the Chester horizon will ever prove profitable, but before abandonment of the pool it may be profitable in many instances to drill extra locations to the 500-foot sand.

COMPRESSED GAS

Isolated experiments have been made with compressed gas in the Bellair pool, but no installations have been made as yet.

Gas

Only about seven wells in the Bellair pool were considered gas wells. Locally, gas was encountered in the Pennsylvanian in the "500-foot" sand. In the west-central part of the pool the 800-foot sand, wherever it occurred, usually contained gas. The data are incomplete, but some wells had initial productions of from one to two million cubic feet of gas per day and the maximum gas pressure (Chester sands) was about 300 pounds. Considerable gas is obtained from the oil wells. The amount was somewhat increased after the adoption of the vacuum.

CHAPTER VII—FUTURE PROSPECTING

FOREWORD

In the area covered by this report future prospecting should be undertaken in the light of an understanding of the conditions of accumulation in the producing pools, and of the geology of the entire area. Much practical information of this sort has been given in considerable detail in Chapters III to VI inclusive, and the fundamental facts have been stated in Chapter II. A brief summary of the conditions of accumulation as now understood will be found on the following page.

Limitations of space have prevented the extended discussion of the theories of the origin and accumulation of oil which had been planned for this bulletin, as mentioned in the abstract. But a few outstanding facts that bear upon these theories and upon the problem of future prospecting are called to mind in the following paragraphs:

(1) Some sands that do not exist in outcrop but which extend over large areas and contain salt water have failed to provide oil production on the many structures that are productive in other sands both above and below them. (See pp. 109–112.)

(2). Sands that yield oil where their porosity is very noticeably decreased produce only salt water on structures where the sand has marked porosity. (See pp. 111–112.)

(3). The pressures of oil, gas, and water encountered in sands definitely known to be isolated cannot be readily explained by hydrostatic head.

(4). Some sands, among them representatives of all producing types, are known to be in direct contact with considerable thicknesses of shales in the locality within which they produce oil. Some of the organic matter in such shales is believed to be convertible to an oil resembling petroleum by the application of heat. The amounts of oil that conceivably could have originated in the shales are considerably greater in any locality than the total oil apparently existing in the sands.

Many questions and problems that arise from these and other observed facts are incompletely solved. Consequently, ideas and theories as to the origin and accumulation of oil based on these facts should be applied cautiously in undertaking future prospecting.

The writer does believe, however, that the facts described in this report argue forcibly for the "in situ" derivation and accumulation of petroleum (—the expression "in situ" being interpreted in terms of sections or townships as opposed to larger areas—), in contrast to the current theory of extensive "gathering areas" which connotes, among other things, considerable uniformity of porosity. However, the assemblage of the facts which indicate an "in situ" derivation could not be made at this time and it does not seem practicable to make the attempt to prove the point.

SUMMARY OF CONDITIONS OF ACCUMULATION

Primary Importance of Bellair-Champaign Uplift

The one condition common to all oil-producing "sands" in the area of this report, whatever their age, and the one therefore apparently most fundamental for oil accumulation, is their presence on the Bellair-Champaign uplift.

The data for delineating the uplift are far from complete, but the approximate limits are indicated on Plates I and XXI. Logs and samples of drill cuttings from holes that may be drilled in the future on and near the uplift, added to the information already in hand, will permit more adequate delineation and interpretation of the uplift and its structural irregularities than was possible in this report.

Importance of Other Conditions

GENERAL STATEMENT

The presence of a suitable sand on the uplift is by no means the only condition necessary for oil accumulation. Study of the pools has made it clear that a variety of other conditions assist in its control. But the generalization can be made that in most instances, whereas Lower Mississippian and older sands require distinct domes, Pennsylvanian and Chester sands, on account of their discontinuity, do not require actual doming for oil production.

On the whole, discontinuity ("dead-ending") of Pennsylvanian and Chester sands, due either to transition of sand to shale or to its termination against an erosional high, is the most common cause of oil accumulation in those sands. However, it happens that these discontinuities are associated with and due more or less directly to Pennsylvanian or pre-Pennsylvanian structure, so that knowledge of the structure and understanding of its relationship to the discontinuities are a decided aid to prospecting for Pennsylvanian and Chester sands.

In general the Lower Mississippian and older sands are either (1) limestones whose upper portions were made more porous by weathering during some ancient period of erosion, or (2) limestones or sandstones sufficiently porous originally to serve as oil reservoirs. These sands are not notably discontinuous and certainly such discontinuity as they do exhibit is not commonly the controlling cause of oil accumulation. "Dead-ending," so important a cause of accumulation in younger sands, is therefore a relatively negligible factor, actual closure being commonly the most important factor in the trapping of oil in Lower Mississippian and older sands.

Thus it is clear that whatever the horizon to be prospected, its structure should first be determined. Not only should the outlines of the Bellair-Champaign uplift be known, but its structural irregularities, particularly closures, as well.

CROSS-FOLDS

Present knowledge of the structural irregularities of the uplift suggests that closed structures on the uplift are related to a series of so-called cross-folding axes which trend a little east of north and west of south. The tentative axes, numbered as on Plate XXI, are listed below in the order of their probability, judging from present data.

Axes of cross-folding

1. Parker pool to Siggins pool.
2. Martinsville pool to South Johnson pool.
3. North Casey pool to York pool.
4. Oakland dome.
5. Middle Casey Township pool.
6.
7. Licking Township.
8. Warrenton to Borton.

The Parker-Siggins axis, No. 1, is the most definite, and is based on (1) Pennsylvanian structure in the Parker and Siggins pools, (2) the axis of structure in the Lower Mississippian in Parker Township, and (3) the apparent presence of a similar Lower Mississippian closure in the Siggins pool.

The Martinsville and South Johnson domes, and the Bellair pool, offer somewhat less data on the Mississippian but the suggested axis, No. 2, is parallel to axis No. 1, and thus seems to strengthen the probability of the existence of both axes.

The North Casey to York axis, No. 3, parallels axes Nos. 1 and 2 and is submitted partly for that reason. The Oakland axis, No. 4, seems to have a similar trend. Axes Nos. 5, 6, 7 and 8 have less structural data to justify their recognition, but as they parallel axes Nos. 1 to 4 their existence is considered probable.

The axes cross the high parts of local structures, but do not necessarily parallel their longer axes, especially in the bedding older than Pennsylvanian. The eight axes are not all considered major folds. Other major and minor axes may parallel them.

If such a system of cross-folds of definite trend exists, as suggested, the knowledge would be of vital importance to future prospecting in the way of guidance of the search for new closed structures.

IMPORTANCE OF STRUCTURAL INFORMATION TO FUTURE PROSPECTING

Throughout this report emphasis has been laid on the close correspondence of many oil pools with known anticlines, domes, folds, flattenings, etc., on the Bellair-Champaign uplift. In addition, emphasis has also been given the fact that other essential features controlling the location of pools are directly related as to origin to some phase of structure. Altogether, it has been made very clear that structure is a fundamental factor, either directly or indirectly, in the location of most of the oil pools, and that knowledge of the structure of the area and the history of its development are of paramount importance in the search for new pools.

Only partial knowledge of local and regional structural and other geologic conditions can be had ahead of the drill in any locality; but application of whatever information happens to be available, especially concerning structure, will in most instances reduce the risk of failure. And the more information there is available, the greater is the possibility of reducing the risks.

It was practical use of such information that led to the development of the new production in the Martinsville area[1] and to the proving of the Oakland dome, as described in Chapter IV under the heading "Core drilling for structure." And it is such information that makes up this report and that forms the basis for the recommendations to follow.

RECOMMENDATIONS FOR FUTURE PROSPECTING

Introduction

The preceding paragraphs, summarizing the conditions of oil accumulation, all point to structure as the fundamental consideration in oil prospecting in this area. It is logical, therefore, that the recommendations for future prospecting made here should be largely based on and discussed in terms of structure.

Recommendations for the Clark County Field and Vicinity

POSSIBILITIES OF PRODUCTION IN RELATION TO CROSS-FOLDS

Recommendations for prospecting in the vicinity of the Clark County field—that is, in the vicinity of the present producing pools north of Crawford County,—will consider first and separately the possible influences of the tentative axes of cross-folding. Thus confusion of the cross-folding effects with sand conditions will be avoided.

In Ts. 8 N. and 9 N. northward on axes Nos. 6 and 7 (Pl. XXI), favorable structural conditions probably exist, but there is no information to show where closures may be located.

Northward from the Martinsville pool a relatively short distance on axis No. 2 in T. 10 N., a productive structure is possible, but southward the axis seems to have been thoroughly prospected except between the south Johnson and the Jasper County pools. The general synclinal condition to the northeast and southwest should be noted.

Northward from the Casey pool on axis No. 5, it is possible, but not probable, that productive structures exist. However, southward in Ts. 8 N. and 9 N. some closing of structure is probable, perhaps near the southwest corner of T. 9 N., R. 14 W.

Axis No. 3 has been partially tested northward without favorable results, but there is still a possibility of a productive structure. There have been shows of oil in northeast Parker Township, but farther north general synclinal conditions exist. Southward, new producing structures are possible, but not probable, partly on account of the presence of the western synclinal basin in that direction.

On axis No. 1 the gas and shows of oil north from the Parker pool suggest that this area may still yield production. Southward beyond the Siggins pool, production is possible but not probable.

[1] Mylius, L. A., Illinois State Geol. Survey Press Bulletins, October, 1919, and July, 1920.

AREAS OF FAVORABLE STRUCTURE IN THE VICINITY OF THE CLARK COUNTY FIELD

The parts of the Clark County field and its vicinity that present data point to as structurally favorable for oil production are listed and described below. The order in which the areas are discussed indicates the relative certainty of the existence of favorable structure, the more definite, best known structures first, and the indefinite, least known last.

For the areas where doming of Mississippian strata is not yet proved, the map giving the elevations of the base of the Lower Mississippian (Pl. XXIV) will be of help. The amount of data available unfortunately is too scant to justify the construction of a contour map. But additional drilling in this territory supplementing the present facts will permit the detection of any doming or local flattening of the Mississippian, and eventually, perhaps, a structure map will be possible.

I.—AREAS OF KNOWN DOMING OF LOWER MISSISSIPPIAN AND OLDER STRATA

PARKER TOWNSHIP DOME

The Parker Township dome, in Ts. 11 and 12 N., Rs. 11 E. and 14 W. (Pl. XXVI), is more definitely known and outlined than any other closure on the uplift. On this dome considerable production is obtained from shallow Pennsylvanian sands which pinch out or are restricted over the dome, and this production was traced off structure and outlined so that it is not likely that any additional Pennsylvanian production exists.

The upper 200 feet, approximately, of Lower Mississippian (depth to top, 300 feet) has some additional production available as shown by the Tables of Well Data for that pool. Its distribution will conform to the bedding and not to the erosional surface as did the pay in the upper 100 feet.

The horizon of the main Lower Mississippian salt water (depth 500-600 feet) does not show any restriction of porosity. Truncated beds at this horizon are not known to be in contact with petroliferous shales. The horizon has been found saturated with salt water on all locations tested to date and it extends over a large area.

The basal Mississippian (Carper sand zone of Martinsville Township) (depth to top about 1,000 feet) has given shows of oil, and in places some oil can undoubtedly be pumped from it.

The dolomitized Devonian crust (depth about 1,200 feet) has given shows of oil, but near the top of the dome the thickness free from salt water is only about 10 feet.

The "Niagara"[2] water sand (depth approximately 1,300-1,400 feet) gives no indication of restricted porosity, and in this locality there is no shale in contact with it. This sand has always been found saturated with salt water and extends over several counties.

The Maquoketa limestone, termed "Clinton" by the drillers, (depth to top, about 2,125 feet) and the Kimmswick or "Trenton" limestone (depth to top about 2,265 feet) undoubtedly will carry oil over this dome, the amount at each location having a direct relation to the configuration of the dome and any variations in porosity. Table 16 summarizes "Trenton" drilling data.

[2]Drillers' nomenclature—it is often in the basal Devonian, not the Silurian.

TABLE 16—*Approximate "Trenton" drilling data tabulated for the sub-areas outlined on Plate XXI.*

Sub-area		Depths to 200 feet into "Trenton"	Part of sub-area	Thickness of drift *a*	Per cent of total depth	Thickness of sand, shale, etc. (easy drilling)	Per cent of total depth	Thickness of lime-stone, thick shells, etc.*b* (harder drilling)	Per cent of total depth	Minimum number casing strings including drive pipe *c*	Size of drive pipe to allow drilling in with 6-inch hole *d*
				Feet		*Feet*		*Feet*			*Inches*
A	Min.	1540	North part, east edge	50	3.2	555	36.1	935	60.7	2; 3 preferable	8¼
	Max.	3925	Southwest	150?	3.8	2175	55.3	1600	40.9	7; 8 preferable	24
B	Min.	1265	Central	150	11.8	160	12.6	955	75.6	2	8¼
	Max.	1905	Around edges	300	15.7	590	31	1015	53.3	2; 3 preferable	8¼
C	Min.	1475	West edge	100	6.7	440	29.8	935	63.5	2	8¼
	Max.	2465	South central	150?	6.1	1180	47.7	1135	46.2	4	12½
D	Min.	1625	North central	100	6.1	590	36.3	935	57.6	2	8¼
	Max.	2425	South and around edges except north edge	200?	8.2	1095	45	1130	46.8	4	12½
E	Min.	1850	Northeast and northwest	50	2.7	870	47	930	50.3	3; 4 preferable	10
	Max.	3525	South central	300?	8.5	1710	48.5	1515	43	5	18

TABLE 16—*Approximate "Trenton" drilling data tabulated for the sub-areas outlined on Plate XXI*—Concluded

Sub-area		Depths to 200 feet into "Trenton"	Part of sub-area	Thickness of drift *a*	Per cent of total depth	Thickness of sand, shale, etc. (easy drilling)	Per cent of total depth	Thickness of lime-stone, thick shells, etc.*b* (harder drilling)	Per cent of total depth	Minimum number casing strings including drive pipe *c*	Size of drive pipe to allow drilling in with 6-inch hole *d*
				Feet		*Feet*		*Feet*			*Inches*
F	Min.	1925	Northeast	50	2.6	975	50.5	900	46.9	3; 4 preferable	10
	Max.	3190	South and Southwest	200?	6.5	1625	51.0	1365	42.7	5	18
G	Min.	2000	Northeast corner	100	5.0	880	44	1020	51.0	3	10
	Max.	5675	Southwest	200?	3.5	2600	46.0	2875	50.5	8	24-in. drive pipe would require 5-3/16-inch casing for last string
H	Min.	1675	North end	50	3.0	600	35.8	1025	61.2	3	10
	Max.	3975	South end	200?	5.0	1825	45.8	1950	49.2	6	20
I	Min.	1790	Northwest corner	50	2.8	710	39.3	1030	57.9	3	10
	Max.	3100	Southeast and south central	200?	6.4	1285	41.5	1615	52.1	5	18
J	Min.	2025	North central	50	2.4	920	45.5	1055	52.1	4	12½
	Max.	2690	Around edges and south	150	5.6	1255	46.5	1285	47.9	4; 5 preferable	12½

K	Min	2225	Northwest corner	50	2.2	1110	49.8	1065	48	4	12½
	Max	4050	South central	200?	4.9	1870	46.1	1980	49	6; 7 preferable	20
L	Min	2475	Northwest	50	2.0	1150	46.5	1275	51.5	4	12½
	Max	3710	Southwest	150?	4.0	1590	43.0	1970	53.0	6	20
M	Min	2465	North central	50	2.0	935	37.8	1480	60.2	4	12½
	Max	3110	Southeast and west edge	150?	4.7	1130	36.5	1930	58.8	5	15½
N	Min	2785	Northwest corner	50	1.8	1135	40.7	1600	57.5	5	15½
	Max	4975	Southeast	200?	4.0	2110	42.5	2665	53.5	7; 8 preferable	24
O	Min	3210	North end	50	1.5	1265	39.4	1895	59.1	5	15½
	Max	4700	Part west edge	200?	4.2	2160	46.1	2340	49.7	7	24
P	Min	2760	North end	50	1.8	1050	38.1	1660	60.1	4	12½
	Max	4200	South end	150?	3.5	1775	42.2	2275	54.3	5; 6 preferable	15½
Q	Min	4100	North	100?	2.4	1675	40.9	2325	56.7	5; 6 preferable	15½

a The drift will not necessarily have its minimum thickness where the thickness of the rock section is at a minimum, and vice versa. Errors in these calculations due to this situation may be corrected by using whatever data are available as to the drift thickness in the particular locality under consideration.

b The limestone on the whole is not very "hard drilling." All gradations exist, but the percentage of limestone and sands that cut the bit is small.

c Extra casing strings for the protection of pays or the elimination of strings by the use of mud-laden fluid are not considered in this calculation. Details on the different waters are included in Chapter V.

d Size of drive pipe determined from casing chart furnished by the National Supply Company.

Most of the "Trenton" drilling in Parker Township has been on edge leases in the hope of averting their abandonment. "Trenton" wells so located are not as good as might be expected on more favorable parts of the dome. An average well in the part worth drilling at present starts at about 100 barrels after shot and drops to 10 in about three months, but from that time on drops little more than one barrel per year.

At this time the deep sand possibilities are not actively prospected as the daily production of the wells for their depth is relatively small. The future however, will doubtless warrant their complete development, and the contour map of the "Trenton" (Pl. XXVI) will be useful in directing drilling. Some hole on the dome, in the area of productive "Trenton," should be drilled to the St. Peter sandstone. If the St. Peter or the Stones River just above is productive anywhere in the area it should produce on this dome.

The Parker dome apparently has a large oil reserve, most of which must wait until the value of oil will warrant more active development.

SIGGINS DOME

Another definitely demonstrated dome which has on it producing Pennsylvanian sands is the Siggins dome, in T. 10 N., Rs. 10 and 11 E. (Pl. XXVII). But the direction of the dome's axis and its relief in pre-Pennsylvanian formations are not yet known.

Over part of the Siggins pool the Pennsylvanian still offers additional possibilities due to deepening. The Tables of Well Data and contours on the lowest Pennsylvanian sand (Pl. XXVII) will be of assistance in such testing. In addition, on the western flank of this structure there is a possibility that a sand, lower in the Pennsylvanian rock section and not represented on the productive part of the dome, may be terminated against the pre-Pennsylvanian surface and cause production on the immediate flank of the present producing area.

The Chester, which may be about 50 feet thick at the top of the dome, will have greater thickness away from the top and also may have sands coming in to the west that are not represented over most of the present producing area. Such sands present the possibility of an irregular strip of Chester production on or close to the west flank of present production.

The Lower Mississippian formation that was subjected to truncation was the St. Louis (depth about 650 feet). As the St. Louis is a fine-grained limestone, the weathering that accompanied the truncation made the cap only slightly porous, and consequently large amounts of oil cannot be expected in the immediate upper portion of the Lower Mississippian on the Siggins dome. However, some oil is in most instances contributed by this horizon, and added to that from other horizons makes a part of the commercial production.

Underlying the St. Louis is the Spergen (depth 875-1075 feet) which is the principal productive horizon of the Parker pool. Capped as the Spergen is by St. Louis in the Siggins pool, weathering had less chance to develop porosity in the Spergen than it did in the Parker pool, but some locations should find the Spergen productive in the Siggins pool.

The condition of the main Lower Mississippian water sand (depth about 1100-1200 feet) is believed to be the same as in the Parker pool. Some petroliferous shale may occur below it and above the Carper sand.

The basal Mississippian (Carper sand), the depth to the top of which s about 1575 feet, has given shows of oil from two of the four holes that went hrough it, and may in the future contribute some commercial production.

The porous uppermost beds of the Devonian (depth about 1825 feet) how more water-free section than at Westfield and have given gas, as noted in igure 11, with shows of oil. In this horizon, additional gas wells are probable and ome small oil wells are possible. In this connection, figure 11 shows the loca-ion of the four holes which penetrate the Devonian and gives elevations on its op. It will be seen that some locations as favorable as that of the good gas vell, hole No. 30 in the NE. ¼ sec. 13, T. 10 N., R. 10 E., are still untested o this depth. Although a great part of the gas has undoubtedly been drawn y the original well, which is old, enough gas may be obtained to make the rilling of gas wells profitable, especially as on some leases the supply of gas or power is small.

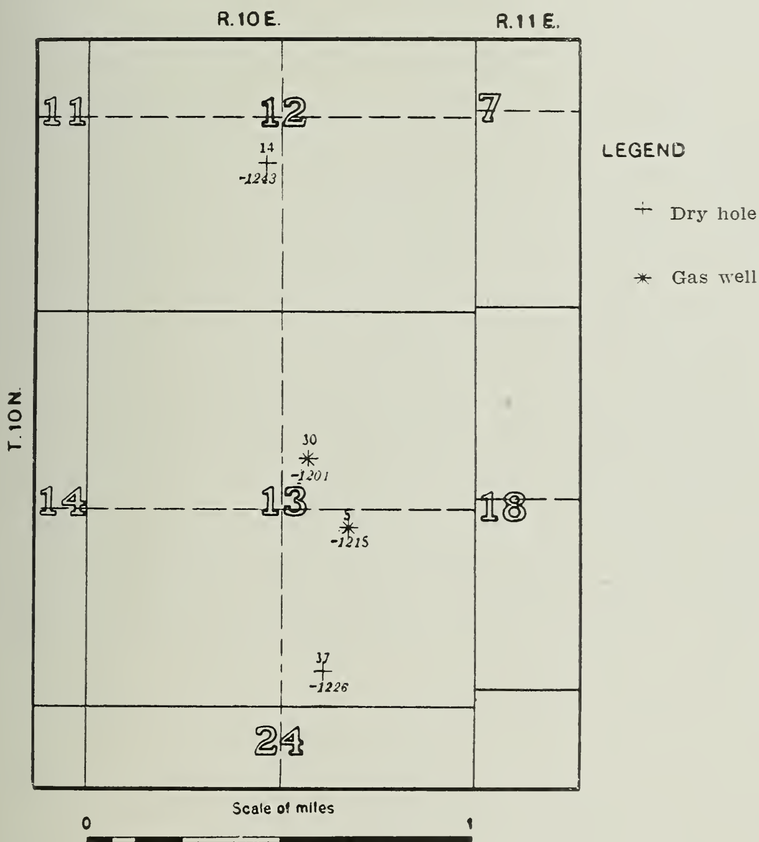


Fig. 11. Map showing the elevations of the Devonian top above sea level in the Devonian gas wells and dry holes of the Siggins pool. The elevations are given in italics. The small numbers above the gas well or dry hole symbols are the reference numbers in the Tables of Well Data.

The water sand of the "Niagara" (depth about 2000-2100 feet) has n been penetrated but conditions similar to those on the Parker dome shoul be expected.

Oil will probably be found in the Maquoketa limestone (depth to top abo 2850 feet and in the Kimmswick or "Trenton" limestone (depth to top abo 3000 feet), and again as in the case of the Parker pool it is a question of th amount of recovery as compared with the cost of drilling these wells. Larg wells are possible but not probable. Long-lived wells can be expected. Tab 16 summarizes "Trenton" drilling data.

MARTINSVILLE DOME

A third definitely known doming of Lower Mississippian and older stra is that of the Martinsville pool (T. 10 N., R. 13 W.) (Pl. XXIX). B as Pennsylvanian production does not extend over the whole dome, the exa direction of its axis, and its extent and relief in the pre-Pennsylvanian form tions, are not yet known.

On this dome the shallow production in the upper 500 feet does not d rectly reflect conditions that will govern production below. The chances f additional light Pennsylvanian production, and for some wells in the weather top part of the Lower Mississippian, which is St. Louis (depth to top abo 500 feet), are good. Most of this production must await a higher price for o

The Spergen (depth about 650-850 feet) was not truncated on the Ma tinsville dome and is therefore not particularly porous. It is not in contact any extent with Pennsylvanian or other petroliferous shales. However, as mo wells are drilled, some will probably find enough oil locally at this horizon warrant pumping.

The main Lower Mississippian water sand[3] (depth about 850-950 fee has seemingly no restriction and also has no contact with petroliferous rocks.

In the Martinsville pool the future of the Carper sand (depth to top abo 1350 feet) is important. Undoubtedly this horizon would provide commerc wells over an area of from one to two square miles, depending on the price oil. In most cases the sand at this horizon is probably present in sufficie quantity to give some oil and undoubtedly will be free from water if the loc tion is sufficiently high structurally. The exact outlines of the Martinsvil dome in the Lower Mississippian will have to be demonstrated by the dri The data and development to date seem to verify an anticlinal axis a little ea of north. The resulting producing area will probably be longer north a south than east and west. Southward, also, on the axis there is a possibility isolated productive spots.

The whole of sec. 30, T. 10 N., R. 13 W., should give production in th Carper sand except along the western edge of the NW. ¼ where the wid of the non-productive strip will have to be determined by the drilling outwa from the center of sec. 30; and along the western edge of the SW. ¼ whe production will probably be found farther west than in the NW. ¼ and m even reach the west section line. Along the eastern edge of sec. 30, producti is expected to reach the east section line in the NE. ¼, but is not expected extend as far east in the SE. ¼ of the section.

[3]The first well of the Trenton Rock Oil Company, Carper No. 1, E. side, NE. NW. ¼ sec. 30, T. 10 N., R. 13 W., Clark County, gave 150 barrels after shot, dropp to about 25 barrels in about a week, but was producing about 20 barrels a day at t end of six months. The average initial production of the first 10 wells was about barrels, settling to from 10 to 35 barrels approximately. The production appears "stand up" exceptionally well.

In sec. 19, T. 10 N., R. 13 W., Carper production should be found in part of the E. ½ SW. ¼ and W. ½ SE. ¼ and possibly in surrounding parts. The locality near the center of the south line of that section would be the best location for tests until drilling progresses outward from sec. 30.

In sec. 31, T. 10 N., R. 13 W., Carper production will probably be found in the NW. ¼. The best location for a test at present is near the center of the north line of the NW. ¼. Some production is also probable in the NW. ¼ NE. ¼.

In the SE. ¼ SE. ¼ sec. 26 and the NE. ¼ NE. ¼ sec. 36, Casey Township, some production is probable.

The exact limits of Carper production will be controlled by the porosity and thickness of sand, factors of more importance locally than the structural situation.

The size and the probable long life of wells from the Carper sand make it rather attractive. The wells so far are not large producers, nor could that be expected from from the nature of the sand, but their settled production is from 10 to 35 barrels per day, which is well above the average of the Clark County field.

On the flanks of the Martinsville dome the Devonian top (depth about 1520 feet), underneath the chocolate shale of the Sweetland Creek, has about 20 feet of water-free sand with shows of oil. Some locations may give wells in this horizon higher on the dome in the area now being drilled to the Carper sand. The "Niagara" water sand (depth 1650-1750 feet) has been found saturated with salt water in the three holes that have penetrated it. The sand is very porous and is not in contact with petroliferous shale. The Maquoketa limestone (depth to top about 2525 feet) and the Kimmswick or "Trenton" limestone (depth to top about 2700 feet) have shown oil on the flanks of this dome and will undoubtedly give wells in locations structurally more favorable. The porosity of the "Trenton" and the show of free oil were greater than at the Parker pool, and it is reasonable to expect some better "Trenton" wells in the Martinsville pool. However, since the depths are 300 feet greater than in the Parker pool, and the probable production not large, the development of these two horizons might well be deferred. "Trenton" drilling data are given in Table 16.

It is evident that considerable oil still remains to be developed on the Martinsville dome and southward along the axis of folding where isolated small areas of production may be encountered. However, prospecting southward in Orange Township is inadvisable until the Carper sand production has been outlined on the Martinsville dome.

II.—AREAS OF KNOWN DOMING OF PENNSYLVANIAN STRATA SUGGESTING PROBABLE DOMING OF OLDER STRATA

SOUTH JOHNSON DOME

The definite doming of the Pennsylvanian strata in the South Johnson pool (secs. 26, 27, 34, and 35, T. 9 N., R. 14 W.) (Pl. XXX) does not definitely demonstrate but strongly suggests that the Mississippian strata are also domed. The dome should be tested below the lower Partlow sand (Pennsylvanian) (depth to top about 600 feet) both east and west of the present producing area, for possible lower Pennsylvanian and Chester sands that may terminate or pinch out over the dome. The maximum depth of a test for the Chester on the crest of the dome would not be over 800 feet, and a depth of

about 1000 feet would be sufficient to test both Pennsylvanian, and Chester o either flank. In addition, at the top of the Lower Mississippian (depth to to about 800 feet) Ste. Genevieve remnants which have been subjected to erosio may exist and offer a chance for wells. But whatever the age of the uppermo strata, the Lower Mississippian crust should locally contain at least small quar tities of oil. The St. Louis and Spergen (depth 800-1400 feet) cannot l expected to provide large production as they did not have sufficient local trur cation to develop marked porosity. Further they have not been in contact t any extent with petroliferous rocks. The horizon of the main Lower Mississip pian waters may show lessened porosity. The Carper sand (depth to top abo 1900 feet) offers a good chance. It will show as much thickness of water-fr section as on the Martinsville dome and should have sufficient porosity t allow some accumulation of oil. Wells much bigger than those found in th Martinsville pool are not to be expected.

The Devonian (depth to top about 2100 feet) offers a chance for pr ductive wells. It may have a greater section free from water than at Martin ville. The "Niagara" water sand should show lessened porosity and there m be some shale in that part of the rock section. The Maquoketa (depth to to about 3250 feet) and the "Trenton" (depth to top about 3400 feet) offer go chances of oil, should the Carper sand testing prove the existence of a Low Mississippian dome. The depths to these horizons, however, are still great than at Martinsville, and, as the wells would be little if any larger, "Trenton and Maquoketa testing should not be undertaken at this time. Table 16 sun marizes "Trenton" drilling data.

It will be seen that this locality has possibilities of considerable addition production below the Pennsylvanian, none of which, however, can be treated a certainty as doming of the lower beds has not been definitely proved.

III.—AREAS OF KNOWN SLIGHT DOMING OF PENNSYLVANIAN STRATA, SUGGESTING POSSIBLE DOMING OF OLDER STRATA

BELLAIR DOME

Another known dome is that on which the Bellair pool (T. 8 N., R. 14 W. (Pl. XXXI) is located. Flattening is marked both in the Chester and in th Pennsylvanian, with production in both; and the scant information available in dicates at least slight doming of the older strata.

In the course of development of the Chester pays, the chance of fla Pennsylvanian production has been rather thoroughly prospected, indicati that such additional production is not probable, though possible.

Some Chester edge wells produce from sands that "dead-end" toward th center of the producing area. The Pennylvanian and Chester are parallel parts of the area, but farther away from the center of the dome or flattenin the divergence in bedding increases and the result is a greater accentuation the Chester dip than of the Pennsylvanian. For these reasons the developme of more production from Chester pay is probable. However, owing to th erratic extent of individual pays and of the weathered Chester top developme may well await higher prices for oil, when a dry hole will take a lesser pr portion of the total profits than under present prices. To obtain all the Chest production in this pool will entail a greater percentage of dry holes than drille up to the present time. The contours on the 800- and 900-foot Chester sar zones indicate many places where they should give wells, but as mentione

e uncertainty in the lateral extent of the porous producing sand reduces the ance of success.

The Lower Mississippian (depth to the top about 1000 feet) probably s a little Ste. Genevieve at the top. This has produced a little oil and undoubtly still other locations will find oil in this horizon. The oil production from is sand will of course be erratic, and here again the question of chance and e amount of the production expected must control prospecting. The St. ouis and Spergen and the Lower Mississippian strata immediately below the ergen are expected to have sufficient porosity to permit oil accumulation only ong the line of possible rock fractures, and such porosity will be extremely regular. They are not in contact with petroliferous shale. The basal Missippian Carper sand (depth to top about 2000 feet) should eventually be ospected on the dome, as the structure is favorable and sand is probably esent. The type of sand occurring in the Carper zone at Martinsville is ch as to indicate that Carper wells in the Bellair pool should not be expected uch, if any, larger than the Carper wells of the Martinsville pool. With ch conditions probable, the total depth and the price of oil will be the factors ciding for or against prospecting.

The Devonian crust (depth to top about 2300 feet) may have less porosity d more water-free rock-section than at Martinsville, and may give some oil d gas. The "Niagara" water sand will probably be less porous than at Marsville and may be in contact with some petroliferous shales due to change in e type of sediment. It is a possible though not probable producer.

The Maquoketa (depth to top about 3400 feet) and the "Trenton" (depth top about 3550 feet) offer good chances for oil. But in view of the great pth and the strong probability that the wells will be little, if any, bigger an those farther north, the prospecting and development of these sands on e Bellair dome will probably await more favorable economic conditions. pecially would this be true if the flatness of the Upper Mississippian structre is repeated in the older strata, for it is questionable whether such structure ill trap oil and gas in the continuous sands typical of the older strata. Those nds that have produced on the Bellair structure to date are discontinuous d therefore react to slight flattening without complete structural closure. n additional element of uncertainty is thus given to prospecting the deeper rizons. Table 16 summarizes "Trenton" drilling data.

IV.—AREAS OF KNOWN DOMING OF PENNSYLVANIAN STRATA; DOMING OF OLDER STRATA QUESTIONABLE

The Central Casey Township dome, the Vevay Park dome and the York me, are three structures known to exhibit doming of the Pennsylvanian strata, t the regional behavior of the underlying Mississippian introduces some queson as to the existence of doming in the Mississippian and older strata. These ree domes will be discussed separately.

CENTRAL CASEY TOWNSHIP DOME

The Central Casey Township dome, located in sec. 14, T. 10 N., . 14 W., (Pl. XXII (B)) offers little chance for the discovery of important eper stray pays in the main sand body within the present productive area.

On the western flank, however, the Pennsylvanian perhaps includes a oductive sand which may terminate against the Mississippian along a narrow

strip in or immediately west of present production. On the western flank, also, the chance exists for some Chester production, although it is slight, as the Chester remnant is rather thin.

The Lower Mississippian crust (depth to top about 475 feet), the St. Louis limestone, has given some oil, and most wells penetrating it on this dome will undoubtedly obtain small production. The amounts, however, will probably be less than at Martinsville. The Spergen (depth to top about 650 to 850 feet), owing to its lesser porosity, is expected to give only erratic production. The condition of the Lower Mississippian water sand will be similar to that at Martinsville. The importance of the Carper sand (depth to top about 1450 feet) depends on the Lower Mississippian structure, regarding which data are lacking at this time. The eastward reversal of the Pennsylvanian and slight data on the Lower Mississippian together with the trend of cross-fold No. 5 suggest eastward reversal of the Lower Mississippian also. However, westward from Martinsville Township, the eroded Lower Mississippian thickens and includes beds progressively higher in the Mississippian section until finally after about 175 feet of thickening, some Chester (Upper Mississippian) is found. It remains, therefore, for drilling to demonstrate whether or not a reversal in the Mississippian bedding exists underneath that of the Pennsylvanian. The dome should be tested to the Carper sand which, if the Mississippian structure proves favorable, should produce oil. The top of the Devonian also would offer some chance of production.

The "Niagara" water horizon is believed to be not much less porous than it is in the several counties to the north. Little if any petroliferous shale exists in that part of the rock section. The Maquoketa limestone (the "Clinton") and the Kimmswick limestone (the "Trenton") are similar to the corresponding horizons in the Parker and Martinsville pools; but perhaps they should not be drilled unless the drilling through the Carper sand and the Devonian demonstrates a closure or marked flattening in the bedding of the Mississippian and lower formations. "Trenton" drilling data are given in Table 16.

VEVAY PARK DOME

In the Vevay Park pool (T. 10 N., R. 10 E.) (Pl. XXVII), the Pennsylvanian does not offer as good a chance for west-flank production as in the main Siggins pool to the north. The Chester should be tested within the area of production, although testing for west-flank production would not seem advisable unless such production is found in the Siggins pool area. Some additional Chester sands may occur to the west, but whether under favorable structural conditions is doubtful. A 1000-foot test should be made southwest of Vevay Park on the chance of finding another structure on cross-fold No. 1. Between the main Siggins pool and the York pool, the Mississippian structure will have to be determined from the results of future drilling. The testing of the deeper horizons should be guided by results in the main pool. There is a possibility of production in the weathered top of the Lower Mississippian lime (depth to top about 800 feet) at Vevay Park, but no deeper testing seems advisable at this time. The approximate depths to the tops of the deeper sands are as follows:

	Feet
Carper sand	1800
Devonian crust	2000
Maquoketa limestone ("Clinton")	3050
Kimmswick limestone ("Trenton")	3200

YORK DOME

In the York pool (T. 9 N., R. 11 E.) (Pl. XXVII), the Chester should be drilled now in the area of production as it is sufficiently thick to offer chances of production. Though the actual structure of the Chester is not known, the general vicinity of the York pool and the area immediately west should eventually have several holes through the Lower Mississippian crust (depth to top, about 1000 feet). But the lower horizons should not be tested until this deeper production has been proved worth while by drilling in the Siggins pool. The approximate depths to the tops of these deeper sands are as follows:

	Feet
Carper sand	2050
Devonian crust	2250
Maquoketa limestone ("Clinton")	3300
Kimmswick limestone ("Trenton")	3500

V.—AREAS OF KNOWN SLIGHT WARPING OF PENNSYLVANIAN STRATA; STRUCTURE OF MISSISSIPPIAN STRATA UNKNOWN

IN CASEY AND JOHNSON TOWNSHIPS

Aside from the Central Casey Township and South Johnson domes already referred to, other slight domings and flattenings of Pennsylvanian strata are known in Casey and Johnson townships (Tps. 9 and 10 N., R. 14 W.). The contours drawn on the Pennsylvanian in Plate XXII (B and C) show these intermediate producing areas with flat Pennsylvanian structure. Some drilling through the main producing sand is warranted in secs. 3, 4, and 5, Casey Township. Where the most prominent sand was unproductive, some wells found production in slightly lower parts of the rock section. Small production may be found by testing still lower sands or lower parts of the same sand that are not represented at the center of the nose, due to termination against the Mississippian erosional high. Pennsylvanian closure of this nose on the north in Parker Township is not proved, but probably exists. The relation between Pennsylvanian and Mississippian structure cannot be determined, as the Mississippian thickens southward from the Parker Township pool an unknown amount. A north dip is probable, but not proved. Thus it would seem inadvisable at present to test the deeper formations in these sections.

The Lower Mississippian crust (St. Louis, depth to top about 400 feet) and the underlying Spergen, however, may contribute some oil in the area where Pennsylvanian sands are now producing. Testing of this possibility would seem advisable, as the drilling of new holes, or the deepening of some of the present wells to a depth of 600 feet, would not be expensive. The Spergen is not to be expected to be as porous as at Westfield. It should show some porosity due to neighboring truncation, with some fractures, and should produce if a Mississippian closure or a marked flattening exists. In some instances the Lower Mississippian crust produces independent of closed structure, whereas Spergen production is controlled more directly by structure. In the absence of definite proof of Mississippian closure, the chance of production in the limestone crust is therefore the better.

The parts of the producing area in Casey Township and the northern half of Johnson Township remaining to be discussed offer changing though similar possibilities. As noted, the eastward rising of the pre-Pennsylvanian surface and the westward thickening of the Mississippian make it impossible

to know the structure below the Pennsylvanian in the area of shallow production from the data at hand. The location of such flattenings or closures as may exist can be learned only by testing. Drilling to the Carper sand may not be warranted at this time, but eventually will show the approximate Mississippian structure; it should precede testing to horizons below the Mississippian. The conditions for production from the different lower horizons are the same as those described for the Martinsville and for the South Johnson pools.

Deepening of the shallow Pennsylvanian wells will no doubt be of some benefit, and locally deepening into the thickened Chester may give some production. To test fully the possibilities for Lower Mississippian crust and Spergen production the holes should go about 300 feet into the Lower Mississippian. This may be the commercial depth limit of tests unless the results of such drilling indicate Mississippian closures.

In sec. 24, Casey Township, and south along the eastern side of Casey and Johnson townships, including only the north half of Johnson Township, there is undoubtedly some chance for light production from Pennsylvanian sands. Production of this type is demonstrated and rather thoroughly tested in Johnson Township, where light wells occur over small areas due undoubtedly to the sand conditions and the flatness of the bedding. In sec. 24, Casey Township, and its vicinity, there is also considerable promise of light wells in the Lower Mississippian crust. The redrilling of the area on the east side of Casey and Johnson townships through the Lower Mississippian crust may be practicable when oil increases in value. It should be emphasized that where Chester is found capping the Lower Mississippian, the Lower Mississippian was subjected only to the pre-Chester truncation and not to the truncation associated with the formation of the Bellair-Champaign uplift occurring in post-Chester time. Therefore, wherever a Chester cap is present, the Lower Mississippian crust is probably less weathered and less porous than elsewhere; and even though the crust is in contact with petroliferous shales, chances of crust production are thought to be slight unless the easily weathered, oölitic Ste. Genevieve happens to be the uppermost Lower Mississippian formation.

Pay other than crust production, that may be found where Chester caps the Lower Mississippian, will be related to structure and may thus guide the testing of deeper horizons. In this locality tests to and including the Spergen will vary in total depth from about 850 to 1200 feet.

AREAS LACKING SHALLOW PENNSYLVANIAN PRODUCTION, BUT DEEPER PENNSYLVANIAN OR CHESTER POSSIBILITIES STILL UNTESTED

PARALLELING KNOWN PRODUCTIVE AREAS

It is not improbable that areas paralleling known Pennsylvanian flattening and also the general anticlinal trend, in which the upper sands are missing or have failed to produce, may carry commercial amounts of oil in lower sands terminating against erosional highs of the pre-Pennsylvanian surface.

Such an area is that paralleling and in general lying immediately west of the Pennsylvanian production in Casey and Johnson townships (Ts. 9 and 10 N., R. 14 W.) (Pl. XXII (B and C)).

In view of the non-deposition of some of the lower Pennsylvanian beds eastward toward the high pre-Pennsylvanian ridge, tests should be drilled on the western edge of the producing area for possible Pennsylvanian sands which do not extend completely over the ridge, and also for possible Chester sands

which do not extend over this ridge but which may exist close enough to the flattened structure to give production. These conditions may result in production along a narrow strip on the western edge of the present producing area. This type of production is illustrated partially at least by the production on the Heim farm, sec. 3, Johnson Township. Such tests, about 850 feet in total depth, would not be costly and would demonstrate the advisability of further prospecting.

ON STRUCTURAL TRENDS BUT STRUCTURE NOT PROVED

Some consideration should be given areas between producing localities on the general trends of the La Salle and Oakland anticlinal belts, as well as areas in which the axes of cross-folding suggest possible closures. Where shallow producing sands are found to be missing or poorly developed, production might be obtained from deeper Pennsylvanian and Chester sands not yet thoroughly tested.

In the area surrounding the producing pools but where definite information on local structures is not available, there are possibilities of structure on the cross-folding axes Nos. 6, 7, 2, 5, 3, and 1. Such areas have more favorable rock section than some of the localities where structure is known, for the Pennsylvanian is thicker. The sand development is lower in the rock section and unless the tests went 1000 feet in some localities, they would not completely disprove the Pennsylvanian. In addition, some thickness of Chester is commonly present. The depth necessary to test adequately any of these areas would not be in excess of 1400 feet, and should production be found, the size of wells would probably be greater than the average of the Clark County field. The logs and other data submitted in the Tables of Well Data will assist the geologist or operator in a study of these localities. The data are somewhat incomplete, but all the information available is given. It is considered advisable to test some of these localities at this time even in the absence of any definite structural knowledge. The testing of the deeper horizons will be warranted only after the Pennsylvanian or Chester has given production or shown favorable structure.

Recommendations for the Area from the Clark County Field North to T. 21 N.

GENERAL STATEMENT

The two anticlinal belts, the La Salle and the Oakland, comprising the western and eastern borders, respectively, of the Bellair-Champaign uplift, are the areas of greatest promise in the territory north of the Clark County field. The margins indicated on Plates I and XXI for these two belts do not delimit the areas in which domes are likely to exist except in a very approximate way, but they do represent the areal trends in which domes are most likely to occur on the uplift. Domes found in these areas may extend somewhat beyond the limits shown on these maps; and domes entirely outside the belts may occur along the cross-folds in the basin between the belts, though the existing evidence does not suggest this as a probability.

The existence of domes or other favorable structures on the uplift is only one of the two questions vital to the problem of future prospecting north of the Clark County field. The other is the occurrence and nature of sands. In general, proving the existence of a dome should be the first step in prospecting

in the area; but localities known to have favorable sand conditions may warrant drilling though the indications of doming are slight.

All domes in the northern area should be thoroughly tested. In the producing area from Lawrence County north, as the cross-section, Plate II, and Table 5 indicate, though the particular parts of the section which produce oil in one locality are absent from other localities, some remaining part has permitted oil accumulation. Or, in other words, as the rock section changes from place to place, different parts of the section come into ideal conditions for oil accumulation. Of course, such conditions cannot be known ahead of the drill, and the writer can only draw attention to the existence of this situation. It should always be remembered that any untested dome may be underlain by some especially favored horizon which may not have been important on any previously tested dome.

Only one closure north of the Clark County field,—the Oakland-Newman dome,—is definitely known, but present information suggests the likelihood of doming in several other parts of the area. Description of the Oakland-Newman dome will be followed by description of the remaining portions of the Oakland belt, and of the La Salle belt.

OAKLAND ANTICLINAL BELT

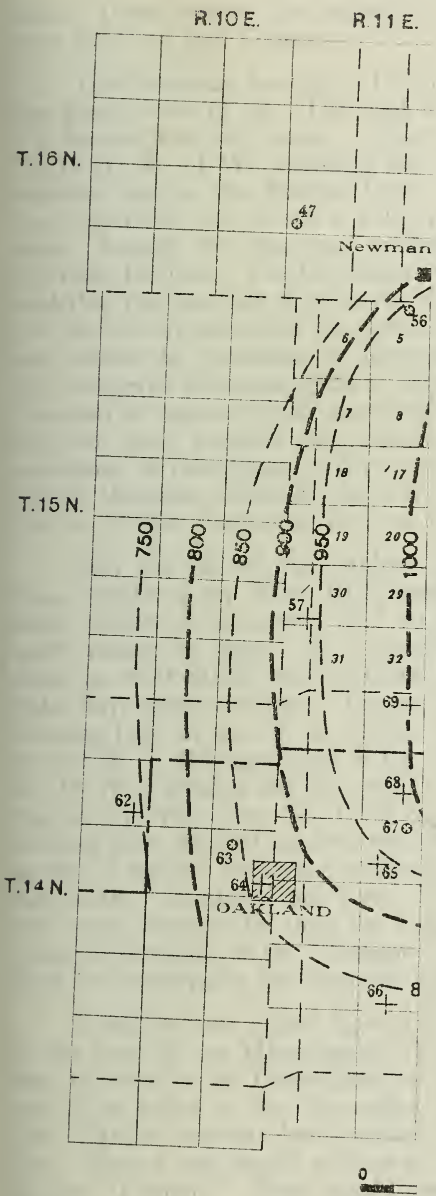
OAKLAND-NEWMAN DOME

The dome between Oakland and Newman, mapped on Plate XX, was discovered by diamond-drilling for structure in the Oakland anticlinal belt. (See Chapter IV, under the heading "Core drilling for structure.") Although the work was not completed, shallow churn drilling has since added sufficient data to make the existence of the dome certain. It is the only definitely known dome north of the Westfield pool.

The Pennsylvanian is very thin, as shown by detailed logs and the data in Table 4, relating to sub-area J. Although light Pennsylvanian production is found on the dome, comparable to that found around Borton and Warrenton on cross-fold No. 8, T. 14 N., R. 14 W. (figs. 12 and 13), the experience with these extremely shallow and irregularly distributed sands indicates that the wells and the individual pools will be small and that therefore thorough development may not be warranted until oil has a considerably higher value. If deeper Pennsylvanian sands, absent over the top of the Oakland dome, were deposited on the steep eastern flank sufficiently near to closure, it is not improbable that larger Pennsylvanian production may be found on the east border of the dome. But as the exact place where the steep eastern dip begins is not known, it may not be advisable to prospect for this type of production at present.

No Chester is present on or near the dome and the chance in the Lower Mississippian is slight. Some Spergen limestone capping the remnant of Lower Mississippian may be found basinward east of this closure, but within the area of influence of this dome most of the Lower Mississippian beds remaining are entirely of sandy shale (Pl. II). With the exception of part of the Upper Kinderhook strata, the sandy shale is not well sorted or porous. The Upper Kinderhook includes a porous sand, equivalent of the Carper, that has given no shows of oil but a hole full of salt water in all holes, including that on the Powers farm in the SW. ¼ SW. ¼ SW. ¼ sec. 22, T. 15 N., R. 14 W. (detailed log No. 55).[4] This porous sand is known to extend over a large

[4]A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.



Structure contour map
(base of the Mississippian)
"Trenton," but all others p
contours on the eastern sid

Approximately at the t
The depth to the top of the
tions between the top of th
the contours. For example
1100) + 670 (approximate e

area. There is some, but markedly less, shale in this part of the rock section here than in Clark County.

The Devonian has 10 to 15 feet of very porous dolomitized crust which has given shows of oil. The sand was oil coated in the vicinity of the dome, but flooded with salt water. The test on the Kite farm in the SE. ¼ sec. 8, T. 14 N., R. 14 W., (detailed log No. 68A)[5] gave the best indication of oil, whereas that on the Powers farm, a well considerably higher on the dome, gave practically no oil but a hole full of water with the bit 1½ feet in the sand. Locally the crust may produce, but there is now no way to ascertain the exact location. The Onondaga (Corniferous) which immediately or closely underlies the chocolate shale in this area, is more susceptible to weathering than the less coralliferous and finer-grained Hamilton. As a result over the large area where the Onondaga is uppermost and was therefore exposed to erosion, the weathered Devonian crust is extremely porous and generally has less local variation in porosity than elsewhere. The upper 150 feet of the Devonian-Silurian strata presents some chance of porosity of the sort developed under conditions of truncation. There are possibilities in the upper part of this Devonian limestone, although there is nothing to indicate that the sandstone at the top of the Silurian or the base of the Devonian will produce.

Near the top of the Oakland dome, the Maquoketa ("Clinton") limestone (depth to top about 1675 feet) and the Kimmswick ("Trenton") limestone (depth to top about 1825 feet) undoubtedly will contain oil, but how much cannot be stated. It is possible that wells located on the crest of the dome as at Westfield will be somewhat smaller than wells elsewhere. Three holes have penetrated the "Trenton" in the vicinity of Oakland, one on the Brading farm in sec. 10, T. 14 N., R. 14 W. (detailed log No. 62),[5] another on the W. J. Hawkins farm in the SE. ¼ SE. ¼ SW. ¼ sec. 29, T. 14 N., R. 14 W. (detailed log No. 65E),[5] and a third on the Rutherford farm in the SE. ¼ SW. ¼ sec. 17, T. 14 N., R. 14 W. (detailed log No. 66).[5] The cuttings from detailed log No. 66 show the "Trenton" to be at least as porous as the "Trenton" producing at Westfield. That hole showed salt-water saturation in the "Trenton," and a very light oil show. However, it is at least 150 feet lower structurally than the top of the dome, and the possible productive range in elevation of the "Trenton top" judging from the conditions at Westfield, is considerably less than this amount.

A shallow hole drilled ¾ to 1 mile east of the west line of Edgar County to the base of the Mississippian, would give data on which to determine the best location for an Ordovician test. If such a hole is not drilled, the dome should be tested to the Maquoketa and "Trenton" at some location close to the 1100-foot contour line as mapped on Plate XX, just east of the county line. Such a test should at least give marked shows of oil, if not production, in the "Trenton." Even should the "Trenton" or a higher horizon fail to produce, a dome of this magnitude deserves a test of the deeper Pennsylvanian possibilities farther east. From the contours on the top of the Devonian shown on Plate XX the top of the "Trenton" can be estimated approximately by subtracting 1075 feet, which is the interval between them. "Trenton" drilling data are summarized in Table 16.

---

[5] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

AREA BETWEEN OAKLAND AND WESTFIELD

In the area between the Westfield (Parker) and Oakland domes, both of which are within the Oakland anticlinal belt, the flattening, illustrated in part by longitudinal cross-section, Plate II, suggests the possibility of a dome, the exact location of which cannot be determined. The record of the Empire test, in the NW. ¼ SW. ¼ SW. ¼ sec. 5, T. 12 N., R. 14 W. (detailed log No. 92)[6] shows the Mississippian and lower formations to be higher than just north of production in the Westfield pool. In that hole as detailed log No. 92 shows, the elevation of the "Trenton" top is 1,553 feet below sea level. In the Endsley hole in sec. 32, T. 12 N., R. 14 W. (detailed log No. 107A)[6] it is 1,716 feet below sea level. In the W. J. Hawkins hole in SE. ¼ SE. ¼ SW. ¼ sec. 29, T. 14 N., R. 14 W., (detailed log No. 65E)[6] it is 1,446 feet below sea level. Just what position the Empire test has in respect to this probable closure cannot be said, but the high part is probably north and perhaps east of the hole.

Northward on cross-fold No. 1 in Edgar County a closure is possible; the area just south of Kansas may be favorable.

Wherever the structure is favorable in the area between Westfield and Oakland, production might be obtained from the shallow Pennsylvanian sands, or the Lower Mississippian limestone, which includes some remnant of porous Spergen, in at least part of this locality. The Carper sand does not offer a good chance of production, nor does the Devonian crust, although both are possible. Undoubtedly the "Trenton" and possibly the Maquoketa will produce oil on any closure. Prospecting to the "Trenton" in this locality should be partially guided by the importance of "Trenton" production on the Oakland and Westfield domes. This area has a somewhat better chance of production above the "Trenton" than the Oakland dome, but the lack of definite structural knowledge more than offsets this advantage. Should the Oakland dome give production from a sand above the "Trenton," that sand will have possibilities in the area between the Parker and Oakland domes.

WARRENTON-BORTON AREA

Cross-fold No. 8 suggests the possibility of closures in all formations in the vicinity of Borton and Warrenton, but no data to prove such closure are available. The different parts of the rock section are very similar to those described for the Oakland-Newman dome. This probable cross-fold offers a chance of Pennsylvanian production northward from Borton. In that direction the thickening of the Pennsylvanian may have resulted in some sands that have a wider distribution which should be productive if there is favorable structure.

The wells in the Warrenton-Borton area (figs. 12 and 13) are light and the sands irregularly distributed.

---

[6] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

AREA NORTH OF THE OAKLAND DOME

ALLERTON AND VICINITY

The existence of a dome or flattened area near Allerton is suggested by the record of a hole in sec. 22, T. 17 N., R. 14 W. (detailed log No. 33)[7]; by the presence of the Marshall-Sidell syncline to the east; by the probability of a reversal of dip to the west; and by the indicated syncline across the strike of the anticlinal belt near Newman. This area would warrant prospecting for structure, partially dependent on the results of drilling the Oakland dome. A dome here would have chances similar to the Oakland dome, including Pennsylvanian production on the east, and somewhat better chances in the crust and the upper 100 feet of the Devonian-Silurian. The Onondaga (Corniferous), which alters into a very porous crust, has possibly been mostly eroded. Present knowledge of the crust does not suggest great or widespread porosity.

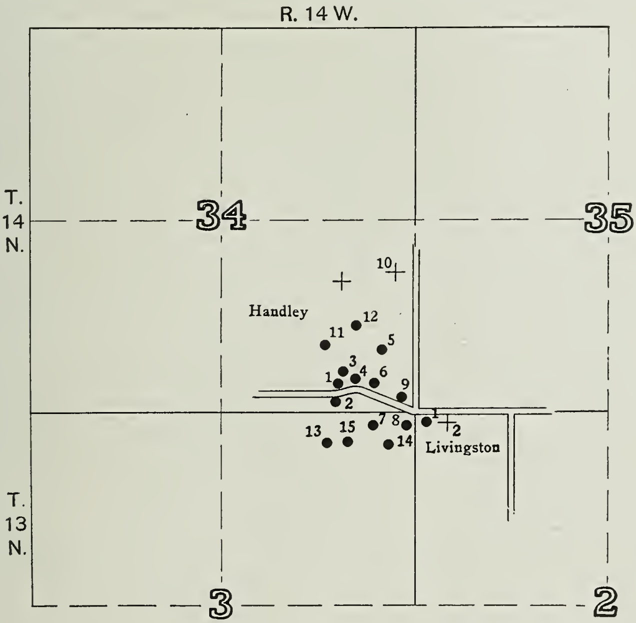


Fig. 12. Map showing the locations of wells and dry holes drilled near Warrenton. The crosses represent dry holes, the black circles wells, and the numbers beside these symbols the farm well numbers. All the available data regarding these wells have been grouped under No. 84 in the detailed logs, a complete set of which is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

Though the location of the erosional highs of the Lower Mississippian top may serve as a general guide to the location of the structural highs, and though the sandy shale of the Lower Mississippian conforms approximately with the Mississippian bedding, the exact structure will have to be verified by drilling to the base of the chocolate (Sweetland Creek) shale. Such testing has the added advantage of showing the nature of the Devonian crust, directly below. The Sweetland Creek shale offers a big potential source of oil, and probably some production will be discovered below it. The truncation of the Devonian-Silurian section before the formation of the Bellair-Champaign uplift is not thought to have caused enough relief locally to result in the formation of porous beds very far below the top of the Devonian-Silurian. Northeast of

the known Oakland dome, on axis No. 4, it is not probable that productive structures exist.

LA SALLE ANTICLINAL BELT

AREA BETWEEN SIGGINS POOL AND TUSCOLA

STRUCTURAL POSSIBILITIES

The area between the Siggins pool and Tuscola may possibly have closures related to the axes of cross-folding. Water wells south of Tuscola have indicated that the anticlinal pitch is slight for three or four miles at least, suggesting the possibility of a structure. North of the town of Hutton, too, in the trend of cross-folding axis No. 4 there may be closures; certainly if a Mis-

Fig. 13. Map showing the locations of the wells and dry holes drilled near Borton. The crosses represent dry holes, the black circles wells, and the numbers beside these symbols the farm well numbers. All the available data regarding these wells have been grouped under Nos. 72 and 73 in the detailed logs, a complete set of which is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

sissippian structural high is proved near Allerton in the northeast trend of axis No. 4, the possibility of closure southward in the trend, near Hutton, would become stronger. The fact that the uplift pitches steeply southward somewhere between Tuscola and the Siggins pool must not be overlooked. Also, locally

the steep western flank of the anticlinal zone will have minor synclinal "embayments" from the Illinois basin. Should closures be partially or entirely located in such an embayment, the greater thicknesses of Pennsylvanian and Chester section there present would provide many favorable sands. Data from the hole on the Rennells farm in the NE. ¼ SW. ¼ sec. 32, T. 12 N., R. 10 E., (detailed log No. 109)[7] might be expected to give definite proof as to whether or not an embayment exists at that point. The description of the samples from this well indicates the non-existence of such a cross syncline, but the evidence is not conclusive because the cuttings were examined and described before the basal Mississippian had been recognized in the area.

In the absence of any definite structural information for the area, prospecting for structure is the logical course preliminary work should take. The key horizons for structure prospecting will be varied. In the northern part of the area holes will find the top of the Devonian limestone a good key horizon at shallow depths. In the southern part, the eroded Lower Mississippian top may be used as a datum for preliminary work, though it will be found somewhat inexact as the uppermost Lower Mississippian strata are sandy shale. Still farther south the typical Mississippian limestone will occur at the top of the Lower Mississippian section and as it is more easily recognized than the sandy shale, will constitute a good key horizon.

The core drill should be used in conjunction with the churn drill in prospecting this area for structure, for the reason that the rock section probably changes very abruptly from place to place, and such changes can best be recognized and their bearing on correlation and on sand chances understood, if cores are available for study.

SAND POSSIBILITIES

In the northern part of the territory lying between the Siggins pool and Tuscola the Pennsylvanian strata are thin, and the possibilities of Pennsylvanian production slight. But deeper strata may produce under favorable structural conditions. Where Burlington strata have not been eroded, they might produce, as they show better sorting of sediments and more shale in this part of the area than elsewhere. The basal Mississippian (Carper sand horizon) has given shows of oil, specifically in two holes in sec. 33, T. 16 N., R. 9 E., east of Tuscola (see detailed logs No. 43 and No. 44).[7] The weathered Devonian-Silurian upper surface presents possibilities, especially as it is capped by the chocolate shale. It lies at comparatively shallow depths. Testing of the "Trenton" possibilities should be considered only where a closure is demonstrated.

The southern part of the territory lying between the Siggins pool and Tuscola has more sand possibilities than the northern part. Thick sands in the McLeansboro of the Pennsylvanian like those in the Siggins pool exist as far north as Charleston, where a massive sandstone which lies stratigraphically well above the producing sands of the Siggins pool outcrops. In other words, it would seem that the Tuscola point of land caused the deposition of considerable thicknesses of Pennsylvanian sands at least as far north as Charleston; and even with relatively small thicknesses of Pennsylvanian, favorable structure may give production. Although no closures are actually known, the chance for good Pennsylvanian and Chester sands in the area just north of the Siggins pool in itself warrants some wildcatting, especially as the depths of adequate tests do

[7] A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

not exceed about 1000 feet. Certainly this locality offers the best chance for production from the equivalent of the Siggins and other shallow sands.

Throughout the area from Tuscola to the Siggins pool there is a chance of terminated sands on the steep western dip of any closures that may exist.

The southern part of the area has all the sand possibilities below the Chester that the northern part has, but the sands are all deeper. Testing for the deepest of the sands, particularly the "Trenton," should not be considered at this time, but should await and be guided by results on demonstrated structure in the northern part of the area.

AREA IN THE VICINITY OF TUSCOLA AND NORTHWARD

STRUCTURAL POSSIBILITIES

The formations in the vicinity of Tuscola are about 2000 feet higher than their equivalents in the Siggins pool, indicating steep southward pitch; but north and northeast of the Tuscola vicinity the dips are relatively slight, suggesting that in this general locality domes probably exist, although their locations may be determined only by drilling. Testing work of this sort should be concentrated within the La Salle anticlinal belt but it should be remembered that parts of domes may extend beyond its limits.

In prospecting the La Salle anticlinal belt for structure north of Tuscola, the use of the diamond drill or a coring device as a control over ordinary churn drilling may easily establish a practical datum other than Devonian or Silurian bedding. Structural highs will undoubtedly be closely related to the erosional highs in the Devonian-Silurian top which is an easy horizon to recognize in ordinary churn drilling. Such an erosional high can afterward be checked for bedding structure by relatively few holes. The maximum stratigraphic variation between the topmost Silurian-Devonian beds anywhere in the area is probably not more than about 100 feet, even where all the capping strata have been eroded. In this vicinity the average depth to the top of the Devonian-Silurian would not average over 350 feet.

SAND POSSIBILITIES

From Tuscola northward the sands that can be expected to give production are few. Pennsylvanian and Mississippian strata are not believed to be present close enough to any closures to offer any chance of production except possibly on the steep western flanks. The Devonian-Silurian might give production locally as the truncation has resulted in many porous beds like those noted in the diamond-drill core taken on the Goff farm in the SW. ¼ sec. 33, T. 16 N., R. 9 E. (see detailed log No. 44),[8] but the possibility of the retention of much oil is to be questioned unless this part of the rock section is shale-capped. In the areas that are structurally highest there is no cap, so that this chance should not be considered important. A fact perhaps significant in this connection is that the water supply for the city of Tuscola is in part at least obtained from the sandstone of the Devonian-Silurian and contains only about 500 parts mineral per million. Somewhat lower Silurian beds may possibly give oil production locally. Undoubtedly the upper Devonian and Silurian beds have a gradual loss in porosity away from the outcrop under the drift until all porosity due to alteration disappears and the beds have only their original porosity. This loss of porosity takes place southward down the main pitch of

[8]A set of all the detailed logs to which reference is made in this report is available for examination upon request to the Chief, State Geological Survey, Urbana, Illinois.

the uplift and possibly to the north, east, and west depending on the dip and extent of previous erosion, in relation to local structures. The Maquoketa limestone and the "Trenton" are the only sands practically certain of production on closures. The wells should be at least as big as those south, and as their depths would be considerably less, smaller wells than the "Trenton" producers in the Parker pool would be profitable in this area. The depth will vary as shown in Table 16 from a probable minimum of 1100 feet to a possible minimum of 950 feet, depending on the behavior of local structures.

Should closures be found from Tuscola northward, the chance of production on the western flank is worth considering. The steepness of the westerly dip as illustrated at Tuscola in cross-section on Plate III, may have resulted in the occurrence of discontinuous Pennsylvanian and Chester sands on the flanks of the uplift, a condition which would offer as possible producing horizons many sands that are absent over the uplift.

Recommendations for the Territory North of the Area of this Report

It is known that limestones of the "Trenton" group (that is, all the limestones between the St. Peter sandstone and the Maquoketa shale) lie at comparatively shallow depths and that probably some closures exist in the trend of the La Salle anticline between Champaign County and the outcrops at La Salle. It is also thought that before the formation of the uplift these limestones were exposed to considerable truncation which resulted in some secondary dolomites. Northward the thickness of this limestone group is known to decrease and the Kimmswick phase which is the uppermost and oil-producing part farther south gradually disappears; but even where the Kimmswick is absent porous dolomite occurs both at and below the top of the limestone. The greater porosity and lesser depth of the "Trenton" group of limestones north of the area of the report encourage and justify search for and prospecting of structural closures within the La Salle zone, as outlined in earlier bulletins.[9]

The Maquoketa shale might be a source of oil for the "Trenton" in this territory.

Recommendations for the Territory South of the Area of this Report

In Crawford County, south of the area of the report, as emphasized by Plates II and XXI, there has been very slight commercial development of pay horizons in the Chester and in the upper part of the Lower Mississippian. Isolated spots, which are noted on Plate XXI, obtain production from undoubted Chester sands, and in a few localities not noted, production may be coming from sands near the top of the Chester. Not more than four or five holes in this whole county have gone through the Chester where the shallower Pennsylvanian has been productive, without obtaining production from the Chester. As noted elsewhere in this report, and in Bulletin 22,[10] the association of Chester production with Pennsylvanian production is marked. The Chester production will be characterized by discontinuity of individual pays and consequently will not need complete structure closures. The Chester structure will not be parallel with that of the Pennsylvanian, though the variance in the area of production will be only slight.

[9] Cady, Gilbert H., The structure of the La Salle anticline: Illinois State Geol. Survey Bull. 36, p. 85, 1920.

[10] Blatchley, R. S., Oil fields of Crawford and Lawrence counties: Illinois State Geol. Survey Bull. 22, 1913.

Especially in the western part of the producing area in Crawford County, there should be considerable testing to and through the Lower Mississippian crust. Such testing would prospect all Chester sands and the McClosky. Testing would be best where the shallow sands produce, but undoubtedly pay will be found in the deeper sands in some places where the shallow sands are not productive. Since the Chester is now producing locally in Crawford County and also north and south of the larger Pennsylvanian producing area of Crawford County, there is undoubtedly a large reserve of Chester oil in this region. In addition there is a possibility of western flank production comparable to that suggested above for the Clark County field.

Study of Crawford County will probably reveal the existence of a system of cross-folds comparable to the cross-folds of the Clark County field.

INDEX

T

U

V